

# FY 2011/12 Annual Research Program Highlights



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# Caltrans Research Program

FY 2011/12

## Annual Research Program Highlights

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Caltrans Division of Research,  
Innovation and System Information

# Division Chief's Message



The California Department of Transportation (Caltrans), Division of Research, Innovation and System Information (DRISI) is pleased to present its FY 2011/12 Annual Research Program Highlights with the intent to share research results and provide a two-year outlook of highlighted active research tasks. This report also fulfills our agreement with the Federal Highway Administration to inform on the progress of Caltrans' research program. This report was made possible by the dedicated DRISI staff, Caltrans programs and districts, and the Research and Deployment Advisory Committee.

This report includes three main sections:

- Research Program Administration – This section summarizes how DRISI ensures a balanced research program that includes Caltrans functional program research, national research programs, research program support partnerships, and university transportation centers.
- Research Task Summary – This summary lists the highlighted research tasks completed in FY 2011/12 and the highlighted active tasks scheduled to be completed in FYs 2012/13 and 2013/14. This summary, organized by Caltrans functional program areas, provides task ID, task title, principal investigator, project manager, task start date, and task end date for each research task.
- Research Results Summaries – These documents provide a high-level summary of the research need, goal, methodology, outcome, and benefit for a selection of our research tasks completed in FY 2011/12.

The Caltrans research program aims to deliver research resulting in products that are an integral part of our organization's commitment to improve mobility across California. During FY 2011/12, we embarked on transportation research covering an array of topics from work zone speed reduction and safety to 3D laser scanning technology. Working with our Caltrans programs and district partners, as well as our academic and transportation stakeholders, FY 2011/12 proved to be an exceptional year for Caltrans research both with regards to our emphasis on ensuring a customer-based research portfolio and to focusing on delivering high quality research products and innovations.

Moving forward, research continues to be a necessary part of our organizational efficiency and effectiveness. At its core, the research process is about collaborating, connecting, sharing and communicating. Over the next year, you can expect Caltrans research staff to work towards a better understanding of the cross-functional benefits of individual research tasks in order to leverage their contribution towards Caltrans strategic goals and objectives.

We welcome your comments, questions, and suggestions. Additional information about our research efforts can be obtained by contacting any of the research staff identified in this report.

COCO BRISENO, *Acting Chief*  
*Division of Research, Innovation and System Information*



Caltrans improves mobility across California by performing applied research, developing innovations, and implementing solutions.

## Research Program Administration

In FY 2011/12, the Division of Research, Innovation, and System Information (DRISI) managed a comprehensive research program addressing Caltrans transportation needs. A viable research program requires the balance of diverse resources to deliver customer needs-driven research results. DRISI and its research partners developed, tested, and evaluated transportation innovations in methods, materials, and technologies enabling Caltrans to provide continual improvement to the management of public facilities and services, protect public investment in transportation infrastructure, and enhance mobility and safety. These research results are achieved by leveraging strengths from the research program partners and resources including Caltrans functional research program, national research programs, research support partnerships, and university transportation centers.

## Caltrans Functional Research Program

DRISI addresses Caltrans research needs in functional program areas including design and construction, environmental, geotechnical and structures, seismic, maintenance, modal, pavement, planning, policy and system information, right of way and land surveys, rural, and transportation safety and mobility. These research efforts are organized by functional program areas to align with Caltrans programs, address critical objectives and goals, maximize research funding, and communicate within and across program areas.

## National Research Programs

Caltrans benefits from national research efforts by partnering with national transportation organizations including Federal Highway Administration (FHWA), Transportation Research Board (TRB), Research and Innovative Technology Administration (RITA), American Association of State Highway and Transportation Officials (AASHTO), National Cooperative Research Programs, Transportation Pooled Funds (TPF), Strategic Highway Research Program 2 (SHRP2), and Every Day Counts 2 (EDC2) to address critical transportation issues and implement solutions to California.

The level of Caltrans participation varies with each national transportation initiative. Caltrans participates in identifying problems for research, serves on committees making recommendations on project selection, serves on panels directing the research, and conducts pilot studies and implementation. In addition, Caltrans participates in Transportation Pooled Fund (TPF) studies to address high priority problems by partnering with FHWA, state, regional and local transportation agencies, and academic institutions to jointly administer research projects. This partnering program enables Caltrans to leverage its resources in experts, staff, and funding.

## **Research Support Partnerships**

In FY 2011/12, DRISI worked with the following University of California affiliated research support partners to meet the research needs and deliver high quality products and innovations to Caltrans: Partners for Advanced Transportation Technology (PATH) Program, Advanced Highway Maintenance and Construction Technology (AHMCT) Center, University of California Pavement Research Center (UCPRC), California Traffic Management Laboratories (CTMLabs), and Pacific Earthquake Engineering Research (PEER) Center. These dynamic collaborations in technical expertise, equipment and materials, research facilities, technology transfer and implementation expertise, training and education are critical to assist DRISI with delivering applied research results.

## **University Transportation Centers (UTCs)**

In FY 2011/12, DRISI worked with the University of California Transportation Center (UCTC) and the Mineta National Transit Research Consortium (MNTRC). UTCs have a strong partnership with Caltrans and are valued intellectual assets in assisting with the state's ever increasing mobility needs. Many of the state's UTCs are working on projects that have been identified as being of key importance, including metropolitan congestion, climate change/greenhouse gas reduction, goods movement, transportation finance, and transportation security. The UTCs also provide training needs through course offerings, support of student dissertations and student participation in research projects that respond to the needs of Caltrans as well as developing a skilled transportation workforce to meet current and future transportation challenges.

# Research Task Summary

This Research Task Summary lists the highlighted research tasks completed in FY 2011/12 and the highlighted active research tasks scheduled to be completed in FYs 2012/13 and 2013/14. Tasks are arranged by functional program areas, and then listed in ascending order by task end date. Each task lists the Caltrans internal tracking number (Task ID), task title, principal investigator, Caltrans task manager, start and end dates. For tasks appearing in bold, a Research Results summary document is included in this report.



Research Tasks Completed in Fiscal Year 11/12



Research Tasks Completed in Fiscal Years 12/13, 13/14

Design/Construction					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2049	Update Safety Roadside Rest Area Master Plan	David Dornbusch	Gloria Gwynne	09/2008	09/2011
0645	Development and Testing of a Low-Profile Barrier	John Jewell	Vue Her	02/2004	03/2012
<b>2247</b>	<b>Evaluation of Radar/CMS Trailer to Reduce Speeds in Work Zones</b>	<b>Bahram Ravani</b>	<b>Randy Woolley</b>	<b>06/2010</b>	<b>04/2013</b>
1094	Effects of Transportation Corridor Features on Driver and Pedestrian Behavior and on Community Vitality	David Ragland	Gloria Gwynne	07/2006	12/2012
2405	Evaluate Photo Speed Enforcement (PSE) in California Work Zones	Bahram Ravani	Hassan Ghotb	05/2012	06/2014

Design/Construction - Pooled Fund Studies					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2294	Enhancements to the FHWA-FST2DH Two-dimensional Hydraulic Model. TPF-5(248)	Kornel Kerenyi	Haniel Chung	01/2011	03/2013
2455	Watershed Modeling System License Renewal Agreement, TPF-5(265)	Kornel Kerenyi	Haniel Chung	01/2012	04/2014
2454	Surface-water Model System (SMS). TPF-5(266)	Kornel Kerenyi	Haniel Chung	01/2012	06/2014

Environmental - Pooled Fund Studies					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1579	Tire/Pavement Noise Research Consortium, TPF-5(135)	Linda Pierce	Harold Hunt	07/2007	12/2012
1578	FHWA Traffic Noise Model: Version 3.0 Software and Training: Pooled Fund TPF-5(158)	Aaron Hastings	Harold Hunt	07/2007	12/2013



Geotechnical/Structures					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2255	Load Testing Bay Bridge Expansion Joints	Ric Maggenti	Joe Holland	03/2011	06/2012
1232	Implementing and Deploying Data Management Tools within Geotechnical Services	Loren Turner	Loren Turner	05/2007	06/2012
1233	Tools and test methods for optimizing design recommendations - Pile Testing	Jason DeJong	Tom Shantz	07/2008	04/2012
0932	Development of Reliable Methods to Analyze Battered Piles and Piles in Sloping Ground	Scott Ashford	Charles Sikorsky	07/2005	06/2012
2384	Load Testing of Bay Bridge Expansion Joint, Phase 2	John Harvey	Joe Holland	11/2011	10/2012
2482	Pilot Study Investigating the Interaction and Effects for State Highway Pavements, Trucks, Freight, and Logistics	John Harvey	Bill Nokes	01/2012	08/2013

Geotechnical/Structures - Pooled Fund Studies					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1010	Structural Acoustic Analysis of Piles, TPF-5(140)	Per G. Reinhall	Harold Hunt	09/2005	12/2012
2298	Evaluation of Seismic Performance of Earth Retaining Structures, Sol-1294	Patrick J. Fox	Tom Shantz	07/2011	06/2013
2347	Imaging Tools for Evaluation of Gusset Plate Connections in Steel Truss Bridges Sol - 1302 TPF-5(259)	Christopher Higgins	Michael Johnson	04/2011	06/2013
2444	Peer Exchange and Review of Deep Foundation Testing Methodologies at Caltrans, TPF-5(263)	Silas Nichols	Harold Hunt	01/2012	09/2013
2401	Shaking Table Testing to Evaluate Effectiveness of Vertical Drains for Liquefaction Mitigation TPF-5(244)	Kyle Rollins	Tom Shantz	07/2011	06/2014

Maintenance					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1738	Evaluation of Pothole Patching Equipment and Processes	Steve Velinsky	Arvern Lofton	06/2008	06/2012
1954	Evaluation of New Technology in Culvert Cleaning (or "Tunnel Mucker") Equipment	Steve Velinsky	Bob Meline	10/2007	06/2012
1103	Research, Identify and Implement How to Reduce Trash on the Roadside	Steve Velinsky	Bob Meline	08/2007	09/2012
2248	Hydrogen Fuel Cell powered lighting trailer evaluation	Steve Velinsky	Hassan Ghotb	01/2011	06/2013
2249	Evaluation of COZEPP and MAZEPP officers use in Caltrans Construction and Maintenance Work Zones	Bahram Ravani	Hassan Ghotb	07/2011	06/2013
2167	Implementation and Evaluation of the Snowplow Driver Assistance System	Bahram Ravani	Larry Baumeister	04/2011	08/2013
1810	Field Operations for GPS assisted Winter Maintenance Vehicles	Bahram Ravani	Larry Baumeister	06/2009	09/2013

## Maintenance

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2220	Evaluation and Development of High Flow Vacuum Systems for Roadway and Roadside Litter Collection	Steve Velinsky	Arvern Lofton	07/2010	09/2013
2338	Continued Evaluation of Pothole Patching Equipment, Materials and Processes	Steve Velinsky	Arvern Lofton	12/2011	09/2013
2215	Deployment Support and Caltrans' Implementation of the Sealzall Machine	Steve Velinsky	Arvern Lofton	07/2010	12/2013
2336	Evaluation of the Tow Plow Trailer System	Steve Velinsky	Larry Baumeister	12/2011	06/2014

## Maintenance - Pooled Fund Studies

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1650	Transportation Security and Emergency Preparedness Professional Capacity, Building (PCB), TPF-5(161)	Dan Ferezan	Jean Vedenoff	02/2007	05/2012

## Modal

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1737	Coaster Station Smart Parking Pilot Project	Susan Shaheen	Robert Justice	07/2008	09/2011
2028	Google Transit: Integrated Trip Planning & Performance Measurements for Small Urban, Rural and Frontier Transit Agencies (The Google Transit Trip Planner for Small and Midsized Transit Agencies)	Dr. Samer Madanat	Bradley Mizuno	10/2009	10/2011
1732	Methodology For Applying Safety Treatments To Rail-Highway At-Grade Crossings	David Ragland	Bradley Mizuno	06/2009	02/2012
1230	EPIC Intermodal Tool Evaluation - Phase 2	Brian D. Taylor	Bradley Mizuno	04/2008	03/2012
1733	Pilot Program to Demonstrate the Benefits of Vehicle-Assist and Automation (VAA) Applications for Full-Size Public Transit Buses	Alex Skabardonis	Sonja Sun	03/2009	09/2012
1910	Planning Tool for Airport Access Phase II	Alexander Skabardonis	Frank Law	05/2011	05/2013
2169	Development Tools for Smart Travel Choices Through Real-Time Information	Masayoshi Tomizuka	Sonja Sun	06/2010	06/2013
2508	Field Operational Tests of Vehicle-Assist and Automation (VAA) System Using Full-Size Public Transit Buses	Roberto Horowitz	Sonja Sun	06/2012	09/2013
2274	Bay Area Rapid Transit (BART) Air Freight - Phase 2	Alexander Skabardonis	Matt Hanson	11/2010	10/2013
2333	Bus Rapid Transit (BRT) Person Throughput-Vehicle Congestion Tradeoffs	Wei-Bin Zhang	Bradley Mizuno	06/2012	11/2013
2521	Interactive Transit Station Information System (ITSIS)	Roberto Horowitz	Bradley Mizuno	03/2012	02/2014
1912	Bay Area Airport Disaster Recovery Plan	Danielle Hutchings	Patrick Tyner	06/2012	05/2014

## Pavement

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1072	Support of Pavement Management System	John Harvey	Joe Holland	06/2007	10/2011
1201	Caltrans Mechanistic-Empirical (ME) Design - Phase 2 Implementation	John Harvey	Joe Holland	05/2007	10/2011
1231	Version 2 Manual for Caltrans Life Cycle Cost Analysis	John Harvey	Joe Holland	05/2007	10/2011
1562	Performance of Warm Asphalt and Low Energy Mixes	John Harvey	Joe Holland	07/2007	10/2011
1874	Laboratory Evaluation of Thin and Modified Asphalt Overlay Mix Design Procedures	John Harvey	Joe Holland	07/2008	10/2011
1878	Integrating Pavement Preservation into the Design Process	John Harvey	Joe Holland	07/2008	10/2011
1879	Field and Heavy Vehicle Simulator (HVS) Evaluation of Extended Life Benefits of Pavement Preservation Treatments	John Harvey	Joe Holland	07/2008	10/2011
1881	4th Year Monitoring of Noise Test Sections (Noise, Texture)	John Harvey	Joe Holland	07/2008	10/2011
1895	Support for Field Projects Involving Recycling	John Harvey	Joe Holland	07/2008	10/2011
1897	Studies to Support Global Climate Change Initiative	John Harvey	Joe Holland	07/2008	10/2011
1948	Asset Inventory Quality Assurance and Network Segmentation	John Harvey	Joe Holland	07/2008	10/2011
2221	Performance of Warm Mix Asphalt and Low Energy Mixes, Phase 3	John Harvey	Joe Holland	07/2010	10/2011
1886	Extended Applications of Rehabilitation Construction Productivity Analysis Products (CA4PRS)	John Harvey	David Lim	07/2008	10/2012
2385	Laboratory and Accelerated Pavement Testing (APT) of Gap-Graded Rubberized Mixes (Hot Mix Asphalt and Warm Mix Asphalt) for the Department of Resources Recycling and Recovery (CalRecycle)	John Harvey	Joe Holland	05/2011	05/2013
2362	Improved Methodology for Mix Design of Open-Graded Friction Courses	John Harvey	Hamid Sadraie	05/2012	06/2013
2352	Early-Age Cracking Performance	John Harvey	David Lim	11/2011	06/2014
2354	Complete QA on Automated Pavement Condition Survey and GPR contracts	John Harvey	Joe Holland	11/2011	06/2014
2355	Differences in Fatigue Performance of Mixes with same PG Binder Grade	John Harvey	Hamid Sadraie	11/2011	06/2014
2371	Life-Cycle Cost and Environmental Life-Cycle Analysis for Composite Pavements	John Harvey	David Lim	11/2011	06/2014
2380	Implementation of New Quieter Pavement Research	John Harvey	David Lim	11/2011	06/2014

## Pavement - Pooled Fund Studies

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1133	Recycled Unbound Pavement Materials (MnROAD Study), TPF-5(129)	Craig Benson	David Lim	05/2007	06/2013
1134	Design and Construction Guidelines for Thermally Insulated Concrete Pavements, TPF-5(149)	Lev Khazanovich	David Lim	01/2007	06/2013
0768	Pavement Tools Consortium, A Web-Based Training System, TPF-5(090)	Joe Mahoney	Joe Holland	01/1990	06/2013
0887	Development of Performance Properties of Ternary Mixes, TPF-5(117)	Carol Culver	Robert Buendia	01/1990	07/2013
0375	Pavement Reconstruction Scheduling Software (CA4PRS), SPR-3(098)	Carl Monismith	Michael Samadian	10/2000	06/2014

## Planning, Policy, and System Information

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1537	Sustainable Transportation Energy Pathways, (STEPs)	Alexander Skabardonis	Patrick Tyner	07/2007	10/2011
1204	Measuring and Modeling Particulate Matter (PM) Emissions from Heavy-Duty Construction Equipment	Matthew J. Barth	Patrick Tyner	05/2007	06/2012
2251	Deployment Support and Data Collection for Caltrans Travel Behavior Survey using the GPS-ATD	Dr. Ty A. Lasky	Bradley Mizuno	06/2010	06/2012
2204	Developing a Hydrogen Transportation Infrastructure	Peter Lehman	Patrick Tyner	05/2011	10/2012
1919	Commercialization of Alternative Fuel (E85) Monitoring System	Matt Barth	Majed Ibrahim	09/2010	06/2013
2243	Spatially Focused Travel Data and Analysis	Marlon G. Boarnet	Robert Justice	12/2011	07/2013
2200	Non-Motorized Travel: Analysis of the 2009 NHTS California Travel Survey Add-On Data	Susan Handy	Robert Justice	08/2011	12/2013
2387	Near-Term Transportation Energy and Climate Change Strategies	Susan Shaheen	Patrick Tyner	03/2012	12/2013
2329	Deployment of Prior High-Occupancy Vehicle (HOV) Lanes Research Results in Developing Analysis Tools for New Managed Lanes Projects	Matt Barth	Robert Justice	04/2012	03/2014
2330	Developing a Model to Quantify Emissions from Heavy-Duty Construction Equipment as Related to Job Site Activity Data	Matt Barth	Patrick Tyner	04/2012	04/2014

## Planning, Policy, and System Information - Pooled Fund Studies

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
0738	Transportation Asset Management (TAM) Research Program, TPF-5(036)	Daniel Yeh	Scott Williams	07/2002	06/2012
1651	Mobile Source Air Toxins (MSAT) from Major Highways, TPF-5(170)	Victoria Martinez	Patrick Tyner	03/2008	09/2012

## Planning, Policy, and System Information - Pooled Fund Studies

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2260	Executive Workshops on Strategies and Best Practices for State Departments of Transportation to Support Commercialization of Electric Vehicles (EV) and Infrastructure, TPF-5(250)	Diane Turchetta	Patrick Tyner	01/2011	12/2012
2300	2012 Multi-State Transportation Asset Management (TAM) Implementation Workshop, TPF-5(245)	Francine Shaw-Whitson	Scott Williams	01/2011	01/2013

## Right of Way and Land Surveying

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2056	Accelerated Project Delivery: Field Use of 3D Terrestrial Laser Scanning on Caltrans Projects	Ty Lasky	Arvern Lofton	12/2008	06/2012
2194	Application of Mobile Laser Scanning for Lean and Rapid Highway Maintenance and Construction	Bahram Ravani	Arvern Lofton	06/2010	09/2013
2517	Mobile Terrestrial Laser Scanning Workflow Development, Technical Support and Evaluation	Bahram Ravani	Arvern Lofton	10/2012	11/2013

## Rural

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2090	Evaluation of an Animal Warning System Effectiveness	Ching Yao Chan	Nathan Loebbs	03/2010	06/2012
1750	Automated Safety Warning System Controller Phase II : Enhancements and Field Tests	Doug Galarus	Sean Campbell	04/2010	03/2013
1746	Professional Capacity Building for Communication Systems Phase II : Plant Wired Communications	Doug Galarus	Jose Perez	06/2011	10/2013
1846	Responder Study Phase III : Enhancements, Specifications and Deployment	Doug Galarus	Melissa Clark	07/2012	06/2014
2283	WeatherShare Phase III : Visualization Tools	Doug Galarus	Sean Campbell	07/2012	06/2014

## Seismic

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1999	Pre-Cast Pier Columns with Energy Dissipating Joints	M. Saiidi	Li-Hong Sheng	07/2006	12/2011
2177	Bridge Design for Earthquake Fault Crossings: Synthesis of Design Issues and Strategies	Rakesh k. Goel	Allaoua Kartoum	11/2010	05/2012
2242	Effect of Vertical Ground Motion on Column Shear Capacity	Sashi Kunnath	Li-Hong Sheng	12/2008	01/2012
1972	Rapid Construction of Bridge Piers with Improved Seismic Performance	Dawn Lehman	Peter Lee	07/2007	09/2012
2240	Required Embedment Length of Column Rebar Cage into Type II Shafts	P. Benson Shing	Charles Sikorsky	01/2008	05/2013

Seismic					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2281	Seismic Design of Column-Footing Connections with Pipe-Pin Hinges for Accelerated Bridge Construction	Said Saiidi	Peter Lee	07/2011	05/2013
2170	Development of Improved Procedures for Seismic Design of Earth Retaining Structures on Conventional and Pile Foundations	Nicholas Sitar	Peter Lee	05/2010	06/2013
2416	California State University, Fresno: Seismic Responses of Mechanically Stabilized Earth (MSE) Walls Using Accelerated Alternative Backfill Materials with Recycled Tire Shreds and Lightweight Expanded Aggregates	Ming Xiao	Peter Lee	05/2012	07/2013
2418	University of California, Los Angeles: Comparative Study of Model Predictions and Data from Caltrans/CSMIP Bridge Instrumentation Program: A Case Study on the Eureka-Samoa Channel Bridge	Ertugrul Taciroglu	Peter Lee	06/2012	11/2013
2173	Impact of Inspection Tube Placement on Structural Performance of Cast-In-Drilled-Hole (CIDH) Piles	P. Benson Shing	Charles Sikorsky	01/2010	12/2013
2176	Seismic Performance of Next Generation Bridges	M. Saiidi	Peter Lee	12/2009	12/2013
2265	Seismic Performance of Connections that Facilitate Accelerated Bridge Construction	Bozidar Stojadinovic	Charles Sikorsky	10/2010	01/2014
2266	Guidelines for Nonlinear Seismic Analysis of Ordinary Bridges: Version 2.0	Bozidar Stojadinovic	Peter Lee	05/2012	05/2014
1793	Deployment and Implementation Support for ShakeCast	David Wald	Loren Turner	03/2011	06/2014
2171	The Stiffness Provided by Girders, Decks, and Soffits Framing Into Integral Bent Caps	Khalid Mosalam	Peter Lee	06/2011	06/2014

Seismic - Pooled Fund Studies					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1731	Full-Scale Seismic Performance Testing of U.S. Highway Bridge Column, TPF-5(180)	Wen-Huei (Phil) Yen	Cliff Roblee	04/2008	06/2012

Transportation Safety and Mobility					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
1116	Deliver a Set of Tools to Resolving Bad Inductive Loops and Correcting Data	Pravin Varaiya and Roberto Horowitz	Joe Palen	11/2006	09/2012
1228	Dedicated Short Range Communications (DSRC) Standards Testing Platform - Phase 2 Exploration of 3 Public Sector Issues	Danijela Cabric	Gloria Gwynne	05/2007	10/2011
2187	High Occupancy Vehicle (HOV) Lane Management System	Pravin Varaiya	Jose Perez	12/2010	10/2011
1215	Deployment of a Tool for Measuring Freeway Safety Performance	Will Recker	Roya Hassas	06/2008	12/2011
1777	Intelligent Roadway Information System (IRIS) Technical Support and Testing	Ty Lasky	Roya Hassas	11/2009	12/2011

## Transportation Safety and Mobility

Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2192	Experimental Evaluation of the Continuous Risk Profile (CRP) Approach to the Current Caltrans Methodology for High Collision Concentration Location Identification	Stephen Anderews	Paul Mazdiyasni	06/2010	03/2012
2250	iCone Deployment	John Slonaker	John Slonaker	08/2011	06/2012
1739	<b>Crash Attenuator Usage Along Travelways and in Work Zones</b>	<b>Steve Velinsky</b>	<b>Vue Her</b>	<b>06/2008</b>	<b>06/2012</b>
1037	Cooperative Intersection Collision Avoidance System (CICAS) (Phase II) (DTFH61-05-H-00021 (FY 09,10)	Alexander Skabardonis	Nathan Loebbs	09/2010	08/2012
1205	District 8 High Occupancy Vehicle (HOV) Facility Performance Analysis	Kanok Boriboonsomsin	Tam Nguyen	12/2008	11/2012
1665	Statewide High Occupancy Vehicle (HOV) Facility Performance Analysis	Alexander Skabardonis	Tam Nguyen	05/2009	12/2012
1795	Evaluation of High Potential Areas for Truck Overweights and Accidents	Alexander Skabardonis	Majed Ibrahim	07/2010	12/2012
1940	Trip-Generation Rates Methodology for Smart-Growth Land-Use Projects	Dr. Susan Handy	Nicole Longoria	11/2008	02/2013
2207	Strategies for Reducing Pedestrian and Bicyclist Injury at the Corridor Level	David Ragland	Jerry Kwong	06/2010	05/2013
1544	Portable Detection Tower	Joe Palen	Joe Palen	04/2007	06/2013
1545	Wireless PTZ Camera Systems	Joe Palen	Joe Palen	04/2007	06/2013
1546	C1 Loop Detector Reader/Analyzer	Joe Palen	Joe Palen	04/2007	06/2013
1559	Evaluate Sensys and Radar Detectors	Joe Palen	Joe Palen	06/2007	06/2013
2062	Augmented Speed Enforcement (aSE) Part 1 of 2 WTI (RID 2146)	Nicholas J. Ward	Ha Nguyen	12/2009	06/2013
2087	Accelerated Reader: Bluetooth Travel Time System	Joe Palen	Joe Palen	03/2009	06/2013
2146	Augmented Speed Enforcement (aSE) Part 2 of 2 (RID 2062)	Alexander Skabardonis	Ha Nguyen	06/2010	06/2013
2206	Crash Attenuator Data Collection and Life-Cycle Tool Development	Bahram Ravani	Vue Her	07/2010	06/2013
2297	California IntelliDrive Test Bed Upgrade (Federal Portion)	Steven Shladover	Asfand Siddiqui	09/2011	06/2013
2272	Field Test the Effectiveness of Adaptive Traffic Control for Arterial Signal Management	Alexander Skabardonis	John Slonaker	08/2011	08/2013
2292	Preparations for Field Testing of Combined Variable Speed Advisory (VSA) and Coordinated Ramp Metering (CRM) for Freeway Traffic Control - PHASE I	Steven Shladover	Hassan Aboukhadijeh	09/2011	08/2013
2223	Coordination of Freeway Ramp Meters and Arterial Traffic Signals Field Operational Test	Alexander Skabardonis	Paul Mazdiyasni	04/2010	12/2013
2209	Pedestrian Safety Improvement Program	David Ragland	Jerry Kwong	06/2010	03/2014
2445	Field Experiment of Coordinated Ramp Metering (CRM)- Phase II	Steven Shladover	Hassan Aboukhadijeh	10/2012	03/2014

Transportation Safety and Mobility					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2293	Enhancement and Technical Support of Intelligent Roadway Information System (IRIS) in Caltrans Districts 1, 2, 5 and 10	Ty Lasky	Roya Hassas	01/2011	05/2014
2302	Action Item 8.09: Develop a Plan to collect Pedestrian Infrastructure and Volume Data for future Incorporation into Caltrans Accident Surveillance and Analysis System Database	David Ragland	Roya Hassas	11/2011	05/2014
2245	Quick Clearance for Major Traffic Incidents - Baseline Study	Alexander Skabardonis	Melissa Clark	09/2010	06/2014
1934	Weave Analysis Matrix and Microsimulation Methodology Refinement	Alexander Skabardonis	Tam Nguyen	06/2012	06/2014
2257	Work Zone Injury Data Collection and Analysis	Bahram Ravani	Hamid Ikram	08/2011	06/2014

Transportation Safety and Mobility - Pooled Fund Studies					
Task ID	Task Title	Principal Investigator	Task Manager	Start Date	End Date
2289	Evaluation of Sign Guide Fonts, TPF-5(262)	Cassandra Isackson	Matt Hanson	07/2011	03/2013
0788	Traffic Control Devices, TPF-5(065)	Amanda Emo	Fred Yazdan	01/2006	06/2013
2061	Support of Research and Deployment of System Ops Applications of VII, TPF-5(206)	Catherine McGhee	Asfand Siddiqui	03/2009	06/2014
0797	Evaluation of Low Cost Safety Improvements, TPF-5(099) (ELCSI PFS)	Roya Amjadi	Nathan Loebis	03/2005	03/2014
2306	Traffic Signal Systems Operations and Management, Pooled Fund Study, TPF-5(258)	Jay Wasson	Melissa Clark	04/2011	06/2014



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## FY 2011/12 Research Results Summaries

DRISI selected a few research tasks to highlight as part of this report. These Research Results documents are organized by topic area and provide a high-level summary of the research need, goal, methodology, outcome, and benefit. These documents were produced with the collaboration of the participants of the tasks.

You can access and download any of these summaries from [www.dot.ca.gov/research/](http://www.dot.ca.gov/research/). For more information about any of these tasks, please contact the Task Manager listed.

The contents of this document reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the California Department of Transportation, the State of California, or the Federal Highway Administration. This document does not constitute a standard, specification, or regulation. No part of this publication should be construed as an endorsement for a commercial product, manufacturer, contractor, or consultant. Any trade names or photos of commercial products appearing in this publication are for clarity only.

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Caltrans Division of Research,  
Innovation and System Information

# Research Results

Design/  
Construction

**MARCH 2013**

**Project Title:**

Evaluation of Radar/CMS Trailers to  
Reduce Speeds in Work Zones

**Task Number:** 2247

**Completion Date:** April 23, 2013

This project investigated whether trailer-based radar and changeable speed signs that display driver speeds are effective in reducing speeds, as compared to positioning a CHP officer on-site or using only cones and lane closures.

**Task Manager:**

Hassan Ghotb,  
Transportation Electrical Engineer  
[Hassan.Ghotb@dot.ca.gov](mailto:Hassan.Ghotb@dot.ca.gov)

## Increasing Safety in Work Zones

*Can radar and changeable message signs reduce speeds significantly in work zones without CHP officers?*

### WHAT WAS THE NEED?

Drivers who don't slow down in construction and maintenance zones are one of the biggest dangers that Caltrans road workers face. The agency spends millions of dollars each year employing the California Highway Patrol (CHP) to enforce posted work zone speed limits by sites during work hours with their lights flashing.

Caltrans and CHP wanted to investigate less expensive and more effective options for reducing traffic speeds in work zones. CHP currently owns Radar Detection and Changeable Message Sign (CMS) trailer units that they wanted to evaluate as deterrents to speeders. If proven effective, these devices could allow CHP to return some of the officers dispatched in work zones for other duties. In addition to a radar detection unit and a portable message sign displaying a driver's speed, these trailers have flashing yellow and blue lights that mimic the presence of a CHP vehicle. Having the blue lights on the trailer requires that CHP transport these units and operate them in the field, requiring CHP presence to deploy them.

### WHAT WAS OUR GOAL?

This field pilot evaluated the use of CHP's Radar/CMS trailers to determine whether these stand-alone trailers are as effective as officer-enforced construction or maintenance zones in reducing traffic speed in work areas.



*Overview of the  
oncoming traffic during  
one of the tests*



Caltrans improves mobility across  
California by performing applied  
research, developing innovations,  
and implementing solutions.

## WHAT DID WE DO?

Caltrans conducted field experiments to compare the average traffic speeds, volume, and lane distribution at key locations in a work zone with and without the use of the CHP Radar/CMS trailer and a CHP officer parked in a patrol vehicle on-site. Average traffic speeds were collected using iCones—radar speed sensors hidden inconspicuously inside orange traffic barrels—and traffic volume and lane distribution information were captured using video cameras mounted on a mast. This test methodology was based on the use of the iCone system and allowed for rapid deployment and collection of average traffic speed.

Three conditions were evaluated: standard lane closure, lane closure with CMS, and lane closure with CMS plus CHP. Data was gathered during the test and then post-processed by researchers to find correlations between trends in the data and conditions.

## WHAT WAS THE OUTCOME?

Based on experimental data, Caltrans found:

- Lane closure alone, with no additional equipment deployed, resulted in a reduction of the average traffic speed of 5 to 5.5 MPH.
- Total lane closure plus the Radar/CMS trailer resulted in a reduction of the average traffic speed by 8 to 12.5 MPH.
- Lane closure plus the Radar/CMS trailer plus the use of a CHP officer in a police vehicle resulted in a total reduction of the average traffic speed of 10.5 to 14 MPH, a slight improvement over the use of the sign alone in the work zone closure.

These results were obtained from a limited number of field tests, and the implication of these findings should be used cautiously. The test also was limited to short-duration work zones, not semi-permanent construction zones.

## WHAT IS THE BENEFIT?

This research demonstrated that using a CHP-operated Radar/CMS trailer in conjunction with a normal maintenance work zone closure slows traffic more than the work zone closure alone. In some work zones, it may be possible to have the CHP position the sign and turn it on and then become a roving resource in and near the work zone, allowing the CHP unit to be more effective than sitting in the work zone with lights flashing. This would provide a more efficient use of resources.

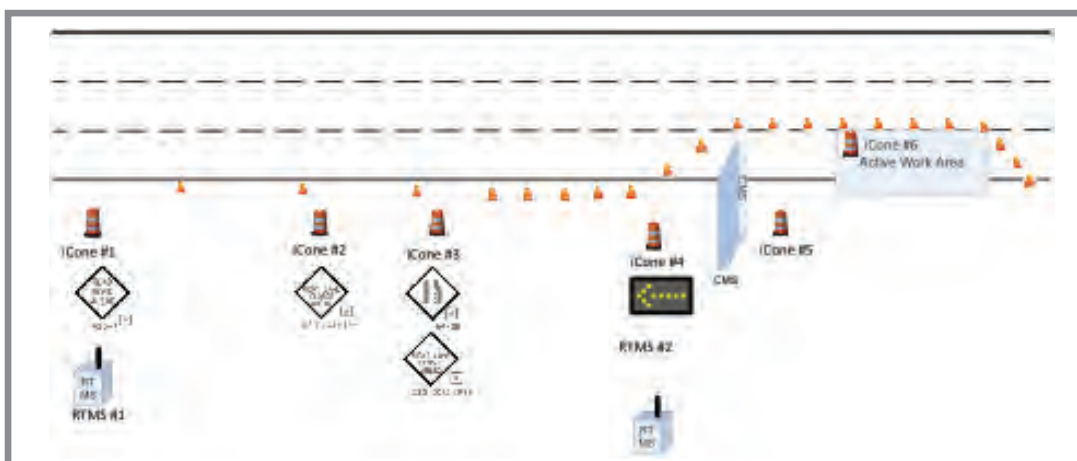
Caltrans is planning to conduct additional research with a similar trailer that uses only yellow flashing lights (no blue light), which could be deployed by Caltrans construction or maintenance personnel without requiring the presence of CHP officers. Future research will also need to determine the criteria to select work zones for yellow-light-only trailers as opposed to using CHP trailers with blue lights.

Based on these results, the use of the CHP Radar/CMS trailer as configured in this study, in combination with an officer, provides for further speed reduction. In the absence of a CHP officer, the CHP Radar/CMS trailer improves the safety in terms of reduced speeds, at least for short duration work zones.

To provide more statistically representative samples, more testing is recommended. Testing in construction work zones is also recommended to see if the results correlate with the data obtained in maintenance work zones. Other factors affecting traffic patterns should be considered in future studies for better understanding of the effectiveness of the CHP Radar/CMS trailer.

## LEARN MORE

The final report will be available on the DRISI website by late spring 2013.



Generic test layout



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Geotech/  
Structures

FEBRUARY 2013

**Project Title:**  
ARS Online

The web-based ARS Online design tool ([http://dap3.dot.ca.gov/shake\\_stable/v2](http://dap3.dot.ca.gov/shake_stable/v2)), helps engineers more easily determine seismic demands that comply with the requirements specified in the Caltrans Seismic Design Criteria.

**Project Manager:**  
Thomas Shantz, Senior Research Engineer  
Caltrans Division of Research,  
Innovation, and System Information  
[tom\\_shantz@dot.ca.gov](mailto:tom_shantz@dot.ca.gov)

## ARS Online Seismic Tool

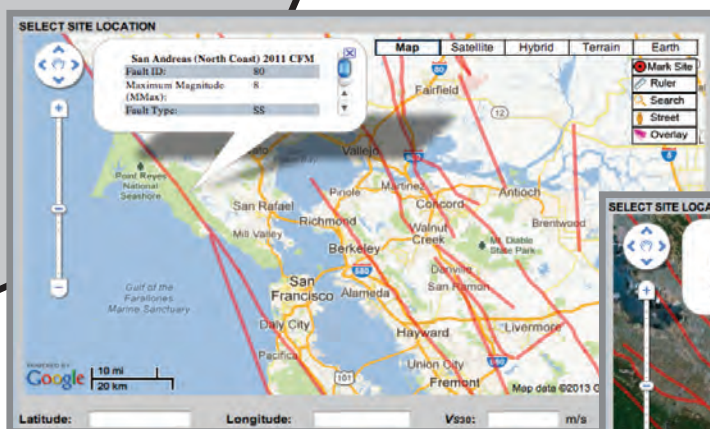
*User-friendly, web-based tool to help engineers assess seismic hazards and determine appropriate design specifications*

### WHAT WAS THE NEED?

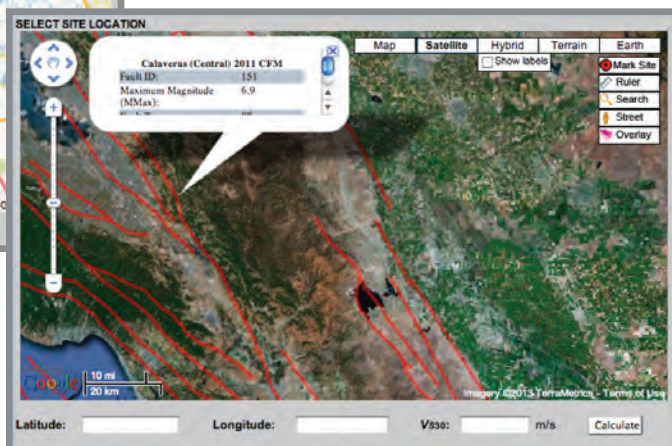
In 2009, Caltrans updated the procedures for determining its Design Response Spectrum to reflect recent advancements in ground-motion prediction equations (GMPEs)—statistical models used to estimate the degree of ground shaking from an earthquake. These models introduce significant improvements in assessing seismic risks, such as amplification caused by near-surface soil and deep sedimentary basins. While the new models are more sophisticated in predicting the severity of ground shaking, they are also more complicated to use. To address the added complexity, as well as minimize the potential for user error, the web-based Acceleration Response Spectrum (ARS) Online tool was developed to help engineers implement these models.

### WHAT WAS OUR GOAL?

The goal was to develop a user-friendly design tool that helps engineers easily and accurately determine a project's seismic loading. In 2009, Caltrans adopted the new GMPEs that are more powerful than previous models, but are also more difficult to use. ARS Online facilitates the adoption of these advanced ground-motion models.



*Known faults are displayed in map, satellite, and terrain views. You can get details of a specific fault by clicking the fault line.*



Caltrans improves mobility across California by performing applied research, developing innovations, and implementing solutions.



## WHAT DID WE DO?

DRISI, working with Geotechnical Services and the Office of Earthquake Engineering Analysis and Research, developed ARS Online to help engineers determine seismic demands that comply with the requirements specified in Caltrans Seismic Design Criteria (SDC). ARS Online features a user-friendly, map-based interface that displays up-to-date information about known faults and their characteristics along with probabilistic ground-motion estimates provided by the U.S. Geological Survey. The user simply specifies the site latitude and longitude coordinates and the near-surface soil stiffness. The tool then provides the SDC design spectrum, along with extensive supporting information needed to verify the result.

To develop ARS Online, the project team:

- Evaluated and selected which GMPE models to use.
- Designed and constructed the web interface.
- Wrote algorithms to perform the various calculations needed.
- Created basin depth maps.
- Rewrote the seismic loading portion of the SDC and developed new guidance documents.
- Performed extensive quality checks.
- Delivered multiple training sessions around the state, including the consulting community.

## WHAT WAS THE OUTCOME?

ARS Online was first released in 2009 and quickly achieved widespread adoption. DRISI continues to improve the tool and make it more robust. ARS Online version 2, released in November, 2012, offers several enhancements, including precise distance measurements and continuously updated faulting information.

DRISI, through the PEER-Lifelines Partnership, maintains a strongly focused program of partnered seismic research that strives to better predict where and how often high levels of shaking might occur. The GMPEs used in ARS Online are a product of this program. Ongoing PEER-Lifelines research on topics such as near-fault ground motion and directionality will lead to additional GMPE improvements that will be incorporated into future versions of ARS Online.

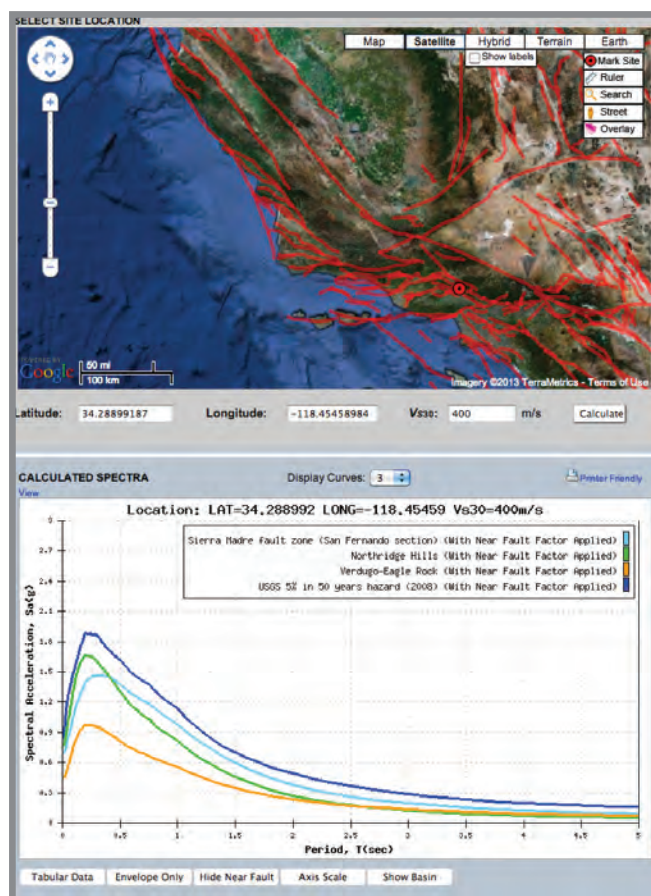
## WHAT IS THE BENEFIT?

Minimizing the risk of seismic activity is a paramount concern in California. Engineers are challenged to meet the requirement for seismic safety while maintaining project cost efficiency. ARS Online provides engineers the information they need to comply with seismic design requirements in a cost-effective and efficient manner.

## LEARN MORE

To access ARS Online, go to  
[http://dap3.dot.ca.gov/shake\\_stable/v2](http://dap3.dot.ca.gov/shake_stable/v2).

To view the guidelines and information used to develop and support ARS Online, visit  
[http://dap3.dot.ca.gov/shake\\_stable/v2/technical.php](http://dap3.dot.ca.gov/shake_stable/v2/technical.php).



*Engineers can quickly calculate the spectral acceleration by simply supplying the site's latitude and longitude and the shear-wave velocity in the top 30 meters of soil.*

## Geotech/ Structures

**MARCH 2013**

### Project Title:

Development of Reliable Methods to  
Analyze Battered Piles and Piles  
in Sloping Ground

**Task Number:** 0932

**Completion Date:** June 30, 2012

In collaboration with Oregon State  
University, Caltrans investigated the  
influence of slope proximity and batter  
on the lateral capacity of driven  
pile foundations.

### Task Manager:

Charles Sikorsky,  
Senior Bridge Engineer  
[charles.sikorsky@dot.ca.gov](mailto:charles.sikorsky@dot.ca.gov)

## Effect of Soil Slope on Lateral Capacity of Piles in Cohesive and Cohesionless Soils

*Developing procedures for analyzing battered piles in  
deep foundations*

### WHAT WAS THE NEED?

Highway bridge piers and abutments are usually supported on deep foundations using driven piles installed at an angle, or batter. Batter piles have an increased capacity to carry lateral loads compared to vertical piles of the same dimensions and materials. However, the procedure to analyze battered piles in these types of applications is very basic and represents a structural system approach that ignores the presence of soil. As a result, the design recommendations are too simplistic, leading designers to follow a conservative design approach that results in higher construction costs.

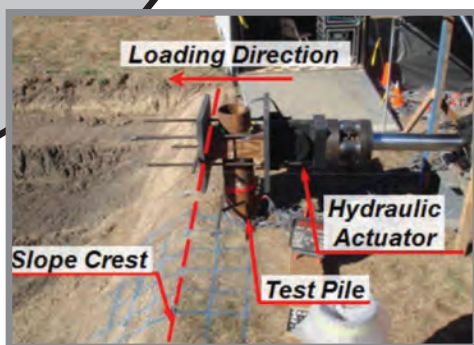
One of the most widely accepted methods for analysis and design of laterally loaded piles is the Winkler spring method in which the soil resistance along the pile is modeled using a series of nonlinear soil springs, commonly known as p-y curves. Most of the standard p-y curves in use are based on the results of full-scale lateral load tests on piles in level ground for a limited range of soil conditions and pile diameters.

Methods that have been recently developed to account for the effect of batter angle and soil slope are generally based on results from analytical solutions and, in the case of cohesionless soils, limited centrifuge test results.

Some of the recommendations have been implemented in current design practice but have yet to be validated with full-scale test results. The available recommendations for cohesive soil slopes are based on analytical solutions and only account for the lateral capacity of short piles. Thus, what is needed is a procedure for the design of battered piles or piles in sloping ground based on results from full-scale tests in both soil conditions.

### WHAT WAS OUR GOAL?

The goal was to analyze the effects of soil slope on the lateral capacity of piles in cohesive and cohesionless soils to improve design guidance for deep foundations.



Test setup



## WHAT DID WE DO?

Two series of full-scale lateral load tests were conducted in cohesive soils and cohesionless soils. A reliable and usable method to predict the lateral force capacity for piles with batter angle and soil slope effect was developed. The study included a series of full-scale lateral loading tests under static loading for two baseline piles. For testing purposes, piles were installed on the crest (OD) and at various pile diameters (2D, 4D, and 8D) from the slope crest, and one pile was installed on the slope. A total of 18 full-scale tests were conducted. For consistency of the test results and to accurately evaluate the effects of soil slope, variations of other factors, such as pile and soil properties, were kept at a minimum.

## WHAT WAS THE OUTCOME?

Based on the experimental and analytical results, the main findings on lateral capacity of piles in cohesive soils are:

- For small soil displacements (less than 0.5 inches), the proximity of slope has an insignificant effect on the lateral pile response. At larger soil displacements, the proximity of slope adversely affects the lateral capacity of piles and consequently the back-calculated p-y curves.
- For maximum allowable pile deflection of 0.25 inches under Service Limit State Load, as mandated in article 4.5.6.5.1 of the Caltrans Bridge Design Specifications (BDS), the slope appears to have an insignificant effect for piles located 2D or more from the slope crest.
- For piles installed on the slope crest, the effect of slope should always be considered at all displacement levels.
- The effect of slope on the lateral capacity was insignificant for piles installed at distances of 8D or greater from the slope crest.

The main findings for cohesionless soils are:

- The effects of slope on lateral pile capacity are insignificant at displacements of less than 2 inches for piles located 2D and greater from the crest.
- For piles located at 4D or greater from the slope crest, the effect of slope is insignificant for the analyzed ranges of soil displacements on p-y curves.
- For all testing cases, the lateral capacity was significantly higher than the 5 kips noted in the Caltrans BDS for 12-inch steel pipe piles for maximum allowable pile deflection of 0.25 inches under Service Limit State Load.

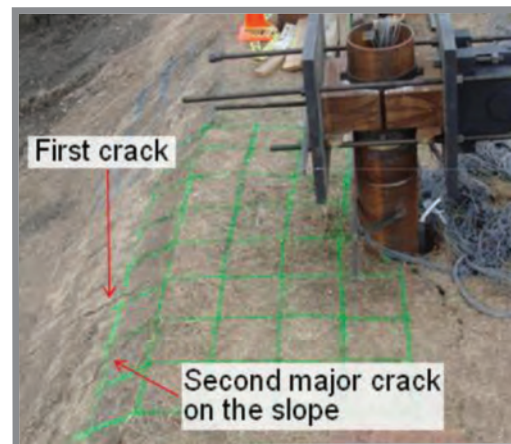
## WHAT IS THE BENEFIT?

Current analysis methods typically overestimate the effects of slope on lateral pile capacities, often resulting in over-compensating the design and costing more to build. This research showed that the influence of slope proximity is minimal approximately two pile diameters away from the slope. In addition, the proximity of the slope is negligible at small pile displacements. As a result, improved design guidance material will reduce the required number of piles in a foundation near a slope, reducing construction costs.

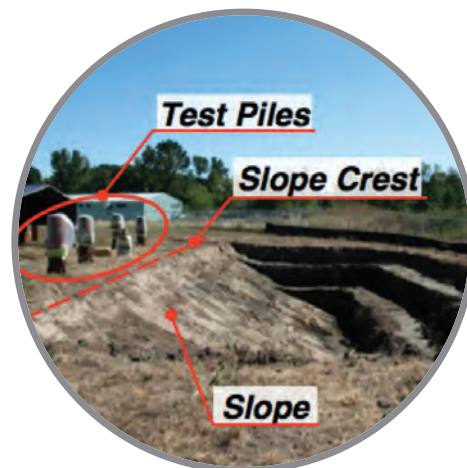
## LEARN MORE

To view the full report:

[www.dot.ca.gov/hq/esc/earthquake\\_engineering/Research\\_Reports/vendor/uc\\_san\\_diego/2012-03/Final%20Report%20CA11-0932%2059A0645.pdf](http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research_Reports/vendor/uc_san_diego/2012-03/Final%20Report%20CA11-0932%2059A0645.pdf)



*Crack pattern at 6-inch pile top displacement*



*Overall view of the completed slope excavation*

## Geotech/ Structures

**MARCH 2013**

**Project Title:**

Implementing and Deploying Data Management Tools within Geotechnical Services

**Task Number:** 1232

**Completion Date:** June 30, 2012

The web-based GeoDOG tool provides a central repository for all Caltrans geotechnical data and documents, giving geo-professionals easy access to essential, up-to-date information.

**Task Manager:**

Loren Turner, Caltrans Senior Transportation Engineer  
[loren.turner@dot.ca.gov](mailto:loren.turner@dot.ca.gov)

## GeoDOG Online Repository

*Comprehensive, web-based tool for efficiently managing Caltrans geotechnical documents and data*

### WHAT WAS THE NEED?

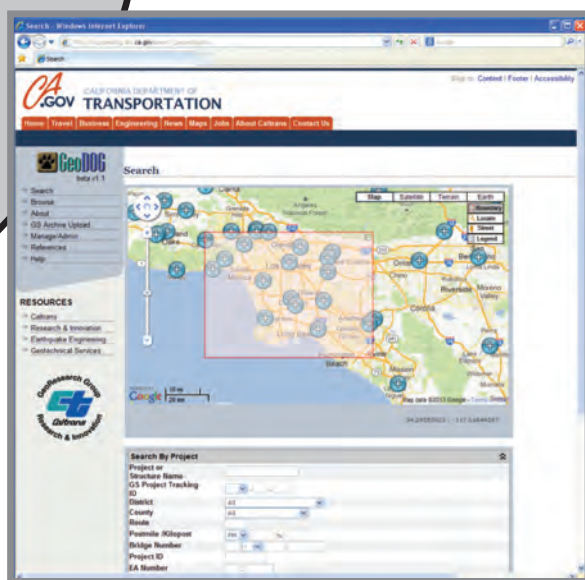
Designing and constructing bridge foundations, retaining walls, and other highway structures requires subsurface exploration and evaluating foundation materials for engineering properties. These geotechnical site investigations generate extensive subsurface information and test data that remain relevant long after the initial project, including being reused for subsequent projects.

To manage the data collected, the Division of Engineering Services Geotechnical Services used a paper-based filing system that was difficult to maintain and cumbersome for geo-professionals to access. Misplaced files, incomplete documentation, the limited lifespan of paper, as well as the inability to know whether the data had already been gathered, contributed to inefficient or incomplete utilization of existing information. The GeoDOG tool was developed to promote the maintenance, management, and reuse of valuable borehole, lab test, and location test data.

A similar implementation of a document management system for the Ohio Department of Transportation resulted in 10% to 20% less borehole drilling with a savings of \$12-\$24 million per year, because existing data could be reused rather than redoing drilling operations for locations where the previous data could not be found. Caltrans conducts approximately 300 geotechnical site investigations annually, each having multiple boreholes. Reducing drilling by 10% by using existing data could save substantial resources annually.

### WHAT WAS OUR GOAL?

The project's objective was to develop a centralized, web-based repository and document management system for Geotechnical Services to improve data collection practices and facilitate rapid archiving, dissemination, discovery, and exchange of information.



*The Search page allows users to look for specific documents or projects within a user-defined spatial boundary.*

## WHAT DID WE DO?

DRISI, in partnership with Geotechnical Services, developed the Digital Archive of Geotechnical Data (GeoDOG) web-based tool for collecting, managing, and retrieving geotechnical documents and data. GeoDOG offers the following:

- Intuitive map-based user interface that presents data availability with tools to search, upload, download, and archive geotechnical documents and data
- Sortable search results, mouse-over information, document preview, and a shopping-cart style document download feature
- Automated email notifications to archive managers and relevant users, providing an efficient means for tracking and approval
- Process controls and tools for archive managers to ensure integrity of the document and data collection
- Facility to share data between the testing lab, geo-professionals, drafting services, and the data repository
- Support for data files generated by commercial geotechnical software used by Caltrans for borehole logs and laboratory test data

Web-coding for GeoDOG was performed in-house under the direction of the principal investigator. Regular interaction with Geotechnical Services end-users ensured that the tool met the fundamental requirements for a functional and deployable system.

Geotechnical Services also contracted a document scanning company to convert over one million existing Caltrans geotechnical documents spanning a period of over 80 years to a digital format, allowing users to immediately take advantage of the GeoDOG document management system.

## WHAT WAS THE OUTCOME?

As of April 2010, concurrent with decommissioning the paper-based filing system, Geotechnical Services requires all geotechnical information to be archived using GeoDOG. In August 2012, GeoDOG was migrated from a locally hosted development server with limited access to an operational IT intranet web server. Subsequent maintenance and operations of GeoDOG are carried out by Caltrans IT.

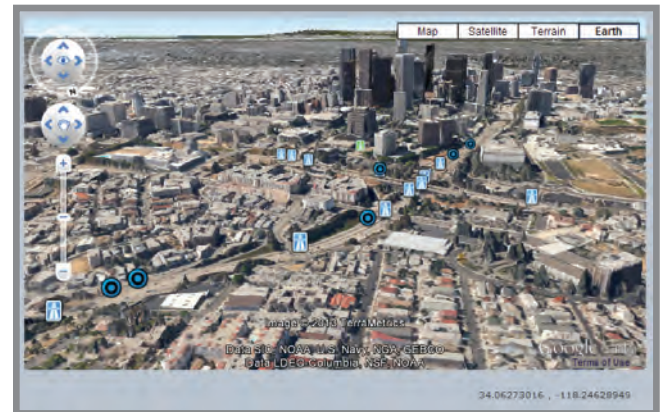
## WHAT IS THE BENEFIT?

With the implementation of GeoDOG, public record requests for geotechnical information are now handled entirely via digital means, significantly reducing the staff time required to respond to requests. With all test data now centralized, users can find past reports, eliminating the need to redo costly tests. The integrity of the data can also be more easily verified because engineers' comments and updates are consolidated and archived.

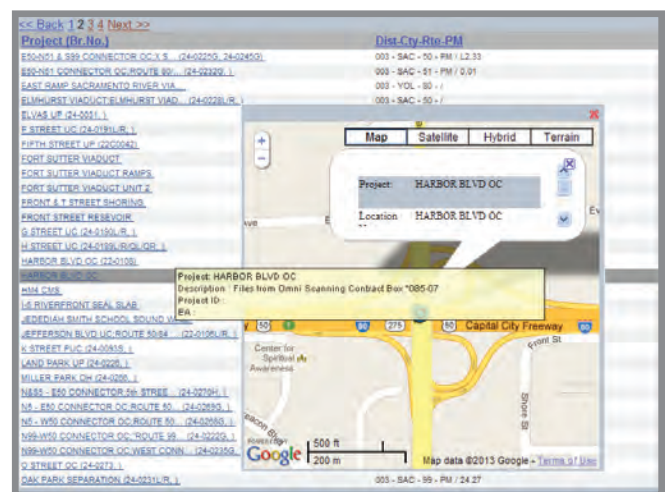
## LEARN MORE

To view the complete report:

[www.dot.ca.gov/research/researchreports/reports/2012/Final\\_Report\\_CA13-1232.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/Final_Report_CA13-1232.pdf)



*Locations of projects and documents in GeoDOG can be visualized using various Google map presentation options, including the Earth view shown here.*



*Search results are presented in tables, organized by project. Users can click a project to view a map of the location, hover the mouse over the project name to get a summary, or click the name to go to the project page.*





Caltrans Division of Research,  
Innovation and System Information

# Research Results

Geotech/  
Structures

**MARCH 2013**

**Project Title:**

Load Testing Bay Bridge  
Expansion Joints

**Task Number:** 2255

**Completion Date:** June 30, 2012

This project tested the ability of a new lane-by-lane expansion joint for the Bay Bridge, which facilitates maintenance and reduces lane closures during repairs, to withstand heavy truck traffic.

**Task Manager:**

Joe Holland,  
Senior Transportation Engineer  
[t.joe.holland@dot.ca.gov](mailto:t.joe.holland@dot.ca.gov)

## Load Testing Bay Bridge Expansion Joints

*Testing whether a new type of thermal and seismic expansion joint can withstand heavy traffic on the Bay Bridge*

### WHAT WAS THE NEED?

The new Bay Bridge consists of three completely different structures. To link these distinct parts requires expansion joints that act in harmony during seismic activity. The type of joints planned for the eastern portion of the Bay Bridge have never been used in California. The new expansion joints are installed lane-by-lane rather than spanning the entire width of the bridge. With the previous expansion joints, all lanes needed to be shut down when maintenance was required.

This new technology, designed by Caltrans and T.Y. Lin International Group, incorporates a Trelleborg Transflex 2400 expansion joint, a steel connector plate, and fastening systems. With these joints, lanes can be closed one at a time, minimizing the disruption of traffic flow. To ensure that the joints are robust enough for California traffic, Caltrans Design Engineers tested the load-bearing capabilities with a Heavy Vehicle Simulator (HVS).

### WHAT WAS OUR GOAL?

The goal was to ensure that the new expansion joints for the Bay Bridge are robust enough to withstand heavy truck traffic.



*Workers assembling the mock-up joint for testing*



Caltrans improves mobility across California by performing applied research, developing innovations, and implementing solutions.

## WHAT DID WE DO?

Caltrans, in partnership with the University of California Pavement Research Center, used an HVS to gain a quick indication of how the joints would perform under truck traffic.

A test structure incorporating a full-scale joint was constructed close to the bridge. A total of 1.36 million load repetitions, equating to about 46 million standard axle loads on a highway pavement, were applied in seven phases during the three-month test. During this test, no seismic or structural testing was undertaken.

## WHAT WAS THE OUTCOME?

No structural damage was recorded by any of the linear variable differential transducers (LVDTs) or strain gauges that were installed on the steel plates, steel frames, bolts, and washers. There was also no visible damage on any of these components. In the last phase of the test, excessive overloading with a 150 kN half-axle load on an aircraft tire, which is approximately four times the standard axle load, caused some damage to the Trelleborg unit in the joint. The damage included abrasion, tearing, shoving, and permanent deformation of the rubber inserts, as well as deformation and shearing of one of the steel supports directly under the wheel load.

Although only limited bounce and no speed effects were considered, based on the results of this limited testing, it was concluded that the expansion joints would perform adequately under typical Bay Bridge traffic. The distresses observed on the Trelleborg unit under high loads in the last phase of testing are unlikely to occur under normal traffic. As expected, the Trelleborg unit was found to be the weakest point of the expansion joint, and these units should be checked periodically to confirm the findings of this study and to assess any effects of higher speeds and vehicle dynamics that were not identified. The joints will require periodic maintenance and replacement in line with the manufacturer's specifications.

## WHAT IS THE BENEFIT?

The findings from this study indicate that the Caltrans seismic expansion joint, when properly installed, are appropriate for typical Bay Bridge traffic. The new joints offer more flexibility during maintenance and repairs because individual lanes can be closed rather than the entire bridge, minimizing traffic disruptions.

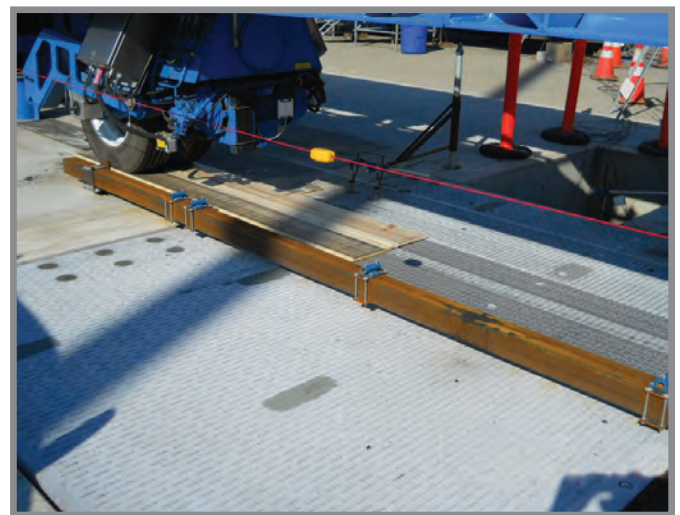
## LEARN MORE

To view the report:

[www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2011-06.pdf](http://www.ucprc.ucdavis.edu/PDF/UCPRC-RR-2011-06.pdf)



*HVS testing on the deck joint*



*Close-up view of HVS testing on the deck joint*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Maintenance

**MARCH 2013**

**Project Title:**

Evaluation of Culvert  
Cleaning Technology

**Task Number:** 1954

**Completion Date:** June 30, 2012

This project evaluated and deployed remote-controlled equipment that can remove debris from culverts in Caltrans maintenance operations.

**Task Manager:**

Robert Meline, Chief, Infrastructure  
Methods Advancement Branch  
[bob.meline@dot.ca.gov](mailto:bob.meline@dot.ca.gov)

## Remote-Controlled Culvert Cleaner

*Increasing the safety and efficiency of culvert cleaning operations*

### WHAT WAS THE NEED?

Culverts channel water under roads and highways. During storms and water flow, debris builds up in the culverts. If the debris is not removed, flooding can cause damage to the surrounding area. Cleaning culverts is a labor-intensive process and, depending on the size, the culverts can be hazardous or difficult to access.

Most medium-sized culverts are cleaned using vacuum trucks with a high-pressure nozzle to wash the debris to the suction hose. Significant manual labor is required to manipulate these tools. The water-logged dirt is then transported to a collection area that can be miles away from the job site. In taller culverts, crews can use earth-moving machines. An operator walks behind the machine as it goes through the culvert, which can be a confined space with limited air supply. Working in confined spaces requires crews to be trained in monitoring procedures and special ventilation equipment.

With remote-controlled tunnel muckers, the operator stands outside the culvert, which reduces physical injuries and hazards related to working in confined spaces. Operators are also not exposed to exhaust fumes and unstable ground. The machines can fit in rectangular culverts as small as 4 feet by 4 feet or round culverts 5 feet in diameter, and are capable of easily removing large rocks and debris. Smaller machines are also available. Another advantage is that no water is used during the operation.

### WHAT WAS OUR GOAL?

The project's goal was to determine the suitability and performance of a small remote-controlled machine for clearing sand, gravel, and other debris from culverts.



*Remote-controlled front-end loader  
cleaning a concrete culvert*



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## WHAT DID WE DO?

Starting in 2008, UC Davis's Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, in partnership with the Caltrans Maintenance Statewide Equipment Managers, evaluated and deployed the MicroTraxx radio-controlled tunnel mucker from ROHMAC, Inc. AHMCT monitored the equipment using cellular-based GPS tracking and collecting feedback from users through site visits and direct contact. Based on the responses, the team implemented various improvements. AHMCT also provided training and equipment support, helping resolve problems with radio communication, mechanical part failures, overheating, and vibration.

## WHAT WAS THE OUTCOME?

AHMCT and Caltrans Maintenance determined that the remote-controlled tunnel mucker is valuable in culvert cleaning operations and have recommended purchasing additional units. The tunnel muckers decrease the cost of culvert cleaning by reducing the equipment and crew size needed for cleaning. The machines can clean culverts four times faster than typical methods and reduce staff exposure to hazardous conditions.

As of 2011, the tunnel mucker has been used in Districts 3, 4, 5, 6, 7, 8, 9, 10, and 11. The equipment has been well received by maintenance crews. As a result of this research project, Maintenance Statewide Equipment Managers has requested acquiring three more culvert cleaning units to use statewide.



*Operator controlling loader.  
Fletcher Creek, Highway 89, District 3*

## WHAT IS THE BENEFIT?

Remote-controlled tunnel muckers improve the safety and efficiency of culvert cleaning operations. They provide a safety and cost benefit to current mid-sized culvert cleaning methods. The machines reduce operational costs, the time needed for cleaning, and the potential for labor injuries. The equipment can be used by any entity, such as cities, counties, or other Departments of Transportation, to maintain culverts that are 48 inches or greater.

## LEARN MORE

To view the evaluation:

<http://ahmct.ucdavis.edu/?projects=microtraxx-tunnel-mucker-evaluation>



*Acton Canyon Wash,  
Highway 14, District 7*



*Wildflower Canyon Road,  
Highway 58, District 6*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Maintenance

**MARCH 2013**

**Project Title:**

Evaluation of Pothole Patching  
Equipment and Processes

**Task Number:** 1738

**Completion Date:** June 30, 2012

This project evaluated automated pothole  
patching equipment to reduce operator  
exposure to oncoming traffic and  
improve the quality of pothole repairs.

**Task Manager:**

Arvern Lofton,  
Transportation Engineer, Electrical  
[alofton@dot.ca.gov](mailto:alofton@dot.ca.gov)

## Automated Pothole Patching Equipment

*Reducing worker exposure to direct roadway traffic when  
patching potholes by using automated equipment*

### WHAT WAS THE NEED?

Highway potholes typically emerge sporadically and rarely occur in concentrated areas, so scheduling traffic lane closures to make urgent patches is impractical. As a result, maintenance crews rely on traffic breaks to make repairs. Frequently, a maintenance worker quickly approaches the pothole during a brief traffic break and casts a lump of cold patch asphalt into the pothole and retreats after thumping it a couple of times with a shovel or boot. Having workers on foot exposed to traffic is always potentially hazardous, but the nature of pothole patching operations makes this task even more risky.

After two Caltrans maintenance workers were killed while patching highway potholes, Caltrans moved to evaluate and deploy innovative automated equipment to reduce worker exposure when conducting highway patching operations.

Automated patching equipment has been on the market for several years and used nationwide. These self-contained machines remove workers from direct traffic exposure because they can be remotely operated from inside the vehicle cab to patch potholes. The machine dispenses either hot asphalt or an emulsion-based spray patch. While both processes have benefits, using hot asphalt is more traditional and has nearly universal support. The target use of this equipment is main and secondary highways with high-speed traffic, which favors the hot patch approach.

### WHAT WAS OUR GOAL?

The goal was to evaluate the effectiveness of automated pothole patching machines to safely assist maintenance crew members in pothole repair operations with reduced direct exposure to highway traffic.



*Python pothole repair*



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## WHAT DID WE DO?

In 2009, the Caltrans Maintenance Equipment Training Academy (META) team, in partnership with UC Davis's Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, reviewed and tested commercially available pothole repair equipment and acquired promising equipment for use by Maintenance staff. The research team, along with Maintenance staff, field-tested the equipment, defining and integrating equipment and process improvements.

The Python Pothole Patcher (PHP) was selected for further review because it was the best match for Caltrans requirements. The PHP automates the traditional hot asphalt patch process with the quality of the resulting patch ranging from long term to permanent, depending primarily on how well the pothole is cleaned prior to patching. To minimize lane closures and traffic disruptions, a patch with sufficient quality can be applied very quickly. If more time is available, the equipment produces a high-quality patch. The machine can be easily configured for different types of patching requirements and is simple to clean.

The PHP was first tested by the District 3 crew in Woodland, California on a two-lane rural highway. The District 3 Sunrise Maintenance crew received limited training in 2009-10. With these initial field tests, design modifications were made to address mechanical issues.

## WHAT WAS THE OUTCOME?

During deployment testing, Caltrans Maintenance personnel with the support of the AHMCT research team explored using the PHP to also patch roadway edge drains. AHMCT collaborated with PHP manufacturer engineers to make the necessary hardware and software modifications to allow pothole patching and edge drain patching operations to occur concurrently.

Based on the PHP evaluation, field-testing, and initial deployment results, Caltrans has decided to continue research toward implementing and supporting full-scale deployment of the PHP. The goal is to maximize the benefit of the automated machine to conduct the majority of pothole patching operations, thereby reducing fixed lane closures. In addition, alternative machines, epoxy-based patching materials, and pothole patching processes will be researched to determine the best practices for patching operations.

## WHAT IS THE BENEFIT?

Automated pothole patching machines enhance the safety of maintenance workers. Compared to manual processes, the equipment also improves the quality of pothole repairs. Safety enhancement and pothole repair quality improvements not only benefit Caltrans, but they also provide advantages to local municipalities, private companies, other Departments of Transportation, and any other entity involved with pothole repairs.

## LEARN MORE

For more information on the PHP machines, including photographs and video recordings of a training session and live deployment, visit:  
<http://ahmct.ucdavis.edu/?projects=python-pothole-repair>



*Python hot-asphalt  
pothole patch*



*Loading Python with  
hot asphalt*



Caltrans Division of Research,  
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# Research Results

Maintenance

**MARCH 2013**

**Project Title:**

Transportation Security and  
Emergency Preparedness Professional  
Capacity Building (PCB) Pooled  
Fund Study

**Task Number:** TPF-5(161), Task 1650

**Completion Date:** May 25, 2012

This project, which was part of a  
pooled fund study among several states  
and the Federal Highway Administration,  
developed a downloadable guide to  
increase the awareness of planners of  
new and retrofitted transportation  
projects about security and emergency  
management considerations.

**Task Manager:**

Jean Vedenoff,  
Transportation Engineer (Civil)  
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## Transportation Security and Emergency Preparedness

*Providing guidance to transportation planners in incorporating security  
and emergency management as part of the development process*

### WHAT WAS THE NEED?

Although it might not be possible to stop a determined terrorist from  
destroying a transportation infrastructure, measures can be taken to minimize  
the possibility and mitigate potential consequences. Especially since  
September 2001, states have been conducting risk and threat assessments  
to determine which prevention, protection, and preparedness measures  
might be required to protect structures, including those that are integral  
to transportation systems, such as bridges, tunnels, highways, and rail  
and aviation facilities. However, the results are not necessarily sent to  
transportation project planners that are designing new infrastructure projects.

Transportation infrastructure project planners are generally not as familiar  
with how to involve emergency management and security considerations  
when developing new infrastructure projects. While awareness of the need for  
infrastructure protection and other aspects of security have increased over the  
last decade, complacency and shrinking budgets have taken their toll. Few  
transportation project planners consider aspects of security when planning  
projects because they simply do not know where or how to start, and they do  
not have a close working relationship with those agencies and individuals that  
work in the security arena at state, regional, or local governments.



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## WHAT WAS OUR GOAL?

The goal was to introduce transportation project planners to the idea of and need for involving various agencies, organizations, and people in developing security and emergency management requirements during the early stages and throughout project development and planning processes.

## WHAT DID WE DO?

Caltrans, in partnership with other donor states that were part of the Federal Highway Administration Transportation Pooled Fund Study, developed the guide, *Considering Security and Emergency Management in the Planning of Transportation Projects*, to increase the awareness of the transportation infrastructure project community, especially those individuals working for a state Department of Transportation (DOT) or a regional Metropolitan Planning Organization (MPO), about security and emergency management. The intended primary audience is planners of new projects responsible for developing highway-related infrastructure projects.

## WHAT WAS THE OUTCOME?

The guide provides the following information:

- Rationale for the consideration of security and emergency management measures when planning transportation infrastructure projects
- Identification of potential partners for project planners
- Examples of measures to be taken
- When to incorporate the measures into the planning process
- Checklist for project planners to guide them through the initial phase of getting partners on board
- References related to security and emergency management, including papers, reports, and websites

The specific security and emergency management measures that might be considered depends on the unique circumstances of the state or region, the transportation system in use, the level of risk willing to be accepted, and the costs of implementing measures in light of possible budget limitations.

## WHAT IS THE BENEFIT?

Incorporating security and emergency management considerations into the planning process increases safety in general, not only in the realm of preventing and protecting against intentional man-made incidents. The steps taken to reduce the impact of these incidents on the transportation infrastructure might also mitigate the effects of a natural disaster or collisions involving hazardous materials. Implementing security and emergency measures when designing new construction projects is typically less expensive and more cost-effective than having to retrofit a structure later.

## LEARN MORE

To view the full report:

[www.planning.dot.gov/documents/ConsideringSecurityAndEM.pdf](http://www.planning.dot.gov/documents/ConsideringSecurityAndEM.pdf)





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# Research Results

Modal

**MARCH 2013**

**Project Title:**

Online Transit Trip Planner for Small  
Agencies Using Google Transit

**Task Number:** 2028

**Completion Date:** October 31, 2011

This project helped small and regional transit agencies in California move dynamic data—schedules—into Google Transit and built a comprehensive and realistic playbook of the time, process, staff requirements, best performance measures, and the costs to work with General Transit Feed Specification (GTFS) standards.

**Task Manager:**

Bradley Mizuno, Transportation  
Engineer (Electrical)  
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## Online Transit Scheduling Using Google Transit

*Small transit agencies can deliver accurate, cost-effective, public schedule data to Internet based trip planners using Google Transit*

### WHAT WAS THE NEED?

The Google Transit Trip Planner, a free e-tool launched in 2005 to provide customers with online trip planning capabilities, is successfully used by transit agencies. While online trip planner tools have been shown to benefit transit riders, streamline agency operations, and enhance customer satisfaction, small and mid-sized transit agencies have been hesitant to sign on.

Transitioning to Google Transit requires dedicated staff time to organize schedule data and convert it to the required General Transit Feed Specification (GTFS) standards—tasks perceived by some smaller agencies as prohibitively time consuming, challenging to current staff capabilities, and costly.

### WHAT WAS OUR GOAL?

The project's objective was to evaluate the challenges that small transit agencies encounter when choosing to use the Google Transit Trip Planner Tool to provide their customers with online transit trip planner access. The Partners for Advanced Transportation Technologies (PATH) at the University of California, Berkeley, in conjunction with Caltrans and the Federal Highway Administration (FHWA), developed a pilot program to help a select number of small transit agencies in California move their service data into Google Transit.

*The project enabled San Luis Obispo-area travelers to use Google Transit to plan trips with connections between regional and city bus lines.*

*Photo Courtesy of Altamont  
Commuter Express*



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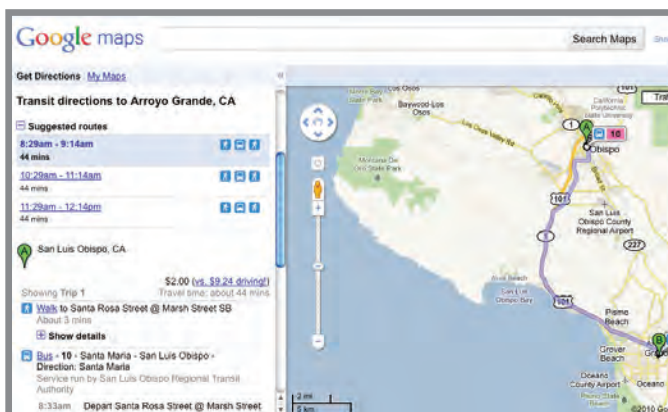


## WHAT DID WE DO?

The selected agencies were provided with resources and tools to help them organize their schedule data, convert it to the required GTFS format, and make it available to Google Transit. The effort was monitored to determine the potential benefits and pitfalls to be expected when small agencies choose to join the Google Transit Trip Planner Tool community.

Most of the participating agencies were able to launch their GTFS data onto Google Transit in less than five months. Consultant costs for the development of the data ranged from \$950 for the agencies with the simplest networks to \$9,400 for the agency with the most complex network. While some agency staff still needed more time to spend on the data conversion effort, most agencies indicated that this effort involved less than 25% of their total staff time over the few months that the GTFS development took place.

Data hosting and maintenance also require relatively limited resources. Because the GTFS data for small agencies often only require a few hundred kilobytes of space on a computer server, this data can easily be hosted on an existing computer server. Data maintenance service contracts can also be signed with consulting firms specializing in such work. Based on data collected between 2009 and 2011, the annual costs of such contracts would vary between \$200 and \$2,800, depending on the complexity of the GTFS data to maintain, the support services included in the contract, and the firm offering the services. While agency staff often expressed fear regarding their ability to develop or maintain GTFS data, experiences from this project indicate that many of the fears can be alleviated through proper documentation and simple hands-on training.



Google trip-planner results from Arroyo Grande to central San Luis Obispo now include a segment from the regional transit district.

## WHAT WAS THE OUTCOME?

This research provides transit agencies with valuable insight into the process of joining Google Transit. Other elements include:

- Review of the needs associated with GTFS data conversion, data maintenance, hosting, security, performance evaluation, and marketing and outreach
- Description of free and subscription-based GTFS development tools available to transit agencies
- Description of a typical GTFS data development process
- Description of various data hosting and maintenance models available to transit agencies
- Identification of training resources available for free
- Technical resources that can be used to assist with the development of GTFS data

## WHAT IS THE BENEFIT?

The pilot deployments demonstrated that the tasks necessary to join the Google Transit Trip Planner require only a relatively short time and minimum staff time commitments when using development tools that are currently available for free. Where the choice exists, the preference should be to develop service data using the GTFS data format. This data format not only allows transit agencies to upload their data onto Google Transit, but also onto multiple traveler information applications developed by independent entities and made available to the traveling public either for free or for a nominal fee.

## LEARN MORE

To view the report:

[www.dot.ca.gov/research/researchreports/reports/2011/2011-09\\_task-2028\\_modal.pdf](http://www.dot.ca.gov/research/researchreports/reports/2011/2011-09_task-2028_modal.pdf)

The project enabled the ACE Train to deliver its data to Google Transit.





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# Research Results

Modal

**MARCH 2013**

**Project Title:**

Rail Crossing Safety Improvements

**Project Number:** P79

This project consists of four tasks commissioned by Caltrans and conducted by University of California, Berkeley researchers between 2002 and 2012 to study the factors contributing to rail crossing collisions and examine affordable, practical solutions that provide drivers with a sufficient level of warning and motivate them to comply with the safety cues.

**Project Manager:**

Bradley Mizuno,  
Transportation Engineer  
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## Rail Crossing Safety Improvements

*New methodologies and technologies to reduce collisions and increase safety at rail crossings*

### WHAT WAS THE NEED?

Grade crossings are an integral part of the railway and highway network. California has 6,433 public at-grade rail-highway crossings. Between 2001 and 2010, 1,033 train-vehicle collisions occurred at these crossings, resulting in 157 deaths and 458 injuries. While the majority of the crossings had only one collision, 29% had multiple incidents in this period, including a few with up to 10.

Many highway-railway crossing sites have rarely or never experienced a collision. Upgrading all grade crossings to a uniform standard is expensive and impractical. Therefore, ranking crossings is necessary to identify where the risk of collision is high and safety measures are most warranted.

To employ cost-effective measures to reduce the number of collisions, Caltrans wanted to identify which factors contribute or predispose a site to collisions and to propose appropriate solutions. Choosing the correct safety treatment for a specific rail-highway crossing requires accurate, up-to-date details about the physical site, traffic, and incidents.

### WHAT WAS OUR GOAL?

The project's objective was to develop a model of rail-crossing violations and the contributing factors to better predict sites that are predisposed to collisions and examine cost-effective methods to increase crossing safety.

### WHAT DID WE DO?

- Formulated a database to compile information on site location and classification, railroad and highway information, traffic control devices, physical characteristics, and incidents.
- Merged two databases from different government agencies to consolidate information on railroad crossings in the San Joaquin Rail Corridor.
- Demonstrated the practicality of using video data gathered from an existing Locomotive Video Data Acquisition System (LVDAS) to capture crossing violations to populate a database to track near-misses and help identify crossings that might be more susceptible or prone to collisions.
- Analyzed driver behavior and other factors that contribute to rail collisions and measures that make it difficult to ignore safety warnings.
- Examined ways to improve commercial off-the-shelf in-pavement warning signals and their suitability for use at grade crossings, and demonstrated a new in-pavement crossing signal based on LED technology.



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## WHAT WAS THE OUTCOME?

Increasing rail crossing safety is highly dependent on the accuracy of the state's inventory database, so bringing the database up to date and putting it into a readily accessible format is important. Properly evaluating crossings is then possible by looking for commonalities at sites where incidents have occurred. Tools such as Google Maps are effective in verifying and updating information in the inventory database.

Although collisions are relatively rare, near-misses are frequent. Therefore, it is important to collect data on crossing violations, because these near-misses offer useful statistical information to identify risk factors for collisions and devise appropriate solutions.

Some type of warning device is present at all public crossings, so most collisions are caused by people violating the signs, signals, or gates and misperceiving an approaching train's distance and speed. Their concern is determining the speed and proximity of the train rather than its presence. However, the interplay of perception, expectation, and human information processing required can easily lead to failures in judging train location and speed. The group of drivers who are not deterred by lowered gates are primarily male and mostly under 40 years old.

One effective solution to rail crossing collisions is to discourage drivers from making faulty decisions. At existing gated locations, median separators and long-arm gates are two low-cost, low-technology, and low-maintenance methods that have been deployed in many locations nationwide. Their efficacy of preventing deaths and injuries has been documented and estimated to reduce collisions by 75%, compared to standard flashing lights and gates.

Gate arms typically extend to the centerline of the road. But when covering at least three-quarters of the roadway, long-arm gates are effective at discouraging gate drive-arounds. Long-arm gates cost less than median separators per crossing, but might not be appropriate for locations with significant truck or bus traffic, wide crossings, multiple rails, or high winds.

Median separators can be applied directly to the existing roadway or part of an island. They present drivers a visual cue and impede crossing to the opposing traffic lane. The curbs are no more than 6 inches in height, usually less than 12 inches in width. The reflectorized delineators, typically 24-36 inches high, can bounce back after being hit or run over and are designed to allow emergency vehicles to cross over into opposing lanes. A system can usually be placed on existing roads without the need to widen them.

## WHAT IS THE BENEFIT?

Caltrans and its partners can use this research to plan for the reduction of injuries, fatalities, and property damage and lessen travel delays resulting from rail and highway shutdowns. Having consolidated detailed information about violations and collisions for each rail crossing is important for identifying on-going dangerous conditions and the type of warnings and obstacles to employ for a particular site, allowing for scarce funds to be used most effectively. This research produced a decision support tool that helps to employ safety measures that are site-appropriate and effective at deterring those drivers who tend to ignore warnings, thereby reducing collisions and saving lives.



Street-mounted  
channelization

## LEARN MORE

To view the complete Caltrans reports, visit:

- Applying Safety Treatment to Rail-Highway At-Grade Crossings  
[www.dot.ca.gov/research/researchreports/reports/2012/2012-05\\_task\\_1732-modal.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-05_task_1732-modal.pdf)
- Driver Behavior at Rail Crossings: Cost-Effective Improvements to Increase Driver Safety at Public At-Grade Rail-Highway Crossings in California  
[www.dot.ca.gov/research/researchreports/reports/2012/2012-05\\_task\\_0747-modal.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-05_task_0747-modal.pdf)
- San Joaquin Rail Corridor Crossing Survey Task  
[www.dot.ca.gov/research/researchreports/reports/2012/2012-05\\_task\\_0990-modal.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-05_task_0990-modal.pdf)
- Improved Grade Crossing Safety with In-Pavement Warning Lights  
[www.dot.ca.gov/research/researchreports/reports/2012/2012-05\\_task\\_0159-modal.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-05_task_0159-modal.pdf)



Caltrans Division of Research,  
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# Research Results

Modal

**MARCH 2013**

**Project Title:**

Smart Parking Value Pricing Pilot  
Program at COASTER Stations

**Task Number:** 1737

**Completion Date:** September 30, 2011

This project investigated commuter behavior and smart parking technologies at transit stations to develop solutions that increase ridership.

**Task Manager:**

Bob Justice,  
Associate Transportation Planner  
[bob.justice@dot.ca.gov](mailto:bob.justice@dot.ca.gov)

## Increasing Transit Use with Smart Parking

*Employing innovative smart parking technologies and strategies to increase the use of mass transit and reduce vehicle emissions*

### WHAT WAS THE NEED?

Lack of parking as well as lack of knowledge of parking availability at commuter rail and transit stations contribute to suboptimal use of transit systems and highway congestion. In the San Diego area, parking had been at or near capacity at many of the COASTER commuter train parking facilities. To not deter ridership, smart parking management technologies were field-tested to cost-effectively address the immediate parking constraints and to develop longer term strategies to expand parking options in the future.

Smart parking incorporates technology and software tools to increase the efficiency and accessibility of parking facilities. It can help users locate parking spaces to reduce idling and frustration, provide real-time information on parking conditions, and allow drivers to reserve spaces and make electronic payments. If adequate transit parking areas are readily available, commuters have an incentive to use mass transit. Innovative smart parking technologies and strategies contribute to alleviating traffic congestion, reducing vehicle emissions, and improving air quality.

### WHAT WAS OUR GOAL?

This project's goal was to analyze commuter behavior and use smart parking technologies to design solutions that increase mass transit use.



*The North County Transit District COASTER commuter train in San Diego County, California*



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## WHAT DID WE DO?

Caltrans, in partnership with the UC Berkeley Institute of Transportation Studies, the San Diego Association of Governments (SANDAG), the North County Transit Agency (NCTD), and ParkingCarma, implemented a pilot project to better understand and ultimately increase COASTER rail line ridership by making parking more efficient using smart parking technology.

The pilot investigated offering reserved premium parking as a means to increase revenue to build more parking areas and add trains, generating more riders per parking space by encouraging carpooling by providing preferential parking, and restricting parking of non-COASTER riders. In addition, information on the real-time availability of parking was made available via the ParkingCarma reservation site and integrated with the 511 traveler information system.

As part of the pilot, the researchers conducted a survey at all stations and parking lots along the COASTER line on the correlation of parking pricing and fares and public transit use. The survey was broken into two groups: Drivers (people who parked at COASTER parking lots, whether they rode COASTER or not) and nondrivers (those who did not drive to a COASTER station).

## WHAT WAS THE OUTCOME?

During the project timeframe, a downturn in the economy lowered ridership and parking demand, which affected the utilization of the parking reservation system. Consequently, the survey responses suggested caution in implementing a new pricing policy. The survey indicated that, with the exception of one station, COASTER parking lots were generally used by COASTER riders. The results showed that COASTER is reducing the need for automotive ownership and driving: 16% of drivers and 30% of nondrivers indicated that if COASTER were not available, their household would have to purchase another car. If COASTER was not available, 71% of drivers and 38% of nondrivers said that they would drive to their destination.

The report includes an analysis of the financial impact of different pricing scenarios on COASTER revenue based on the survey data and recommendations for the existing economic climate. At overcrowded parking facilities, pricing is a strong tool for allocating demand efficiently and recovering the operational costs of parking, and it is also more fair for riders who use alternate access modes. With improved decision-making tools, transit agencies can analyze parking investments to examine the tradeoffs of expansion, advanced parking management systems, and real estate development.

## WHAT IS THE BENEFIT?

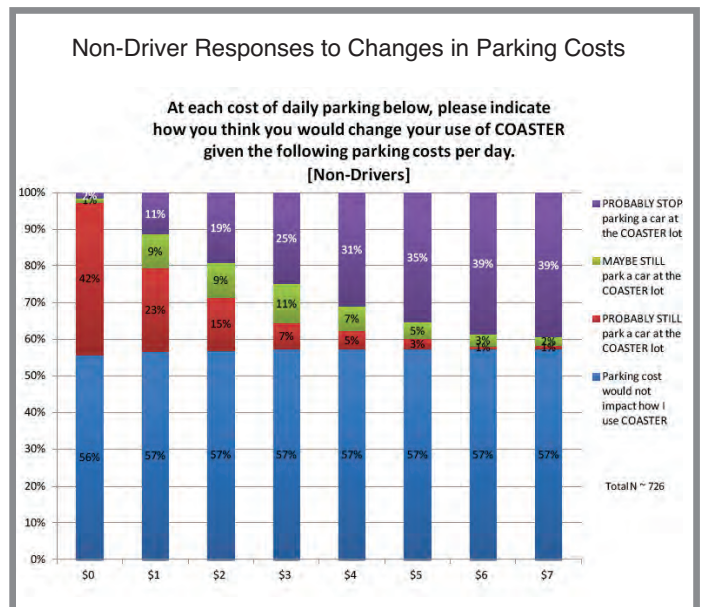
Public transit agencies need to be able to ebb and flow with the economic situation. Advances in sensor, payment, and enforcement technologies help operate parking facilities more efficiently, enhancing customer parking experiences, increasing the supply of existing parking with minimal investment, and raising ridership and overall revenue. Smart parking systems can further expand ridership by generating revenue to add parking capacity and improve access. Advanced parking management systems make transactions easier for customers, gather useful data for improving parking management, and help with enforcement.

A public transit business model that incorporates smart parking technologies reduces commuter time and frustration, encourages transit ridership, reduces pollution, congestion, and fuel consumption, optimizes the existing parking infrastructure, and increases revenue to communities and transit properties.

## LEARN MORE

To view the complete report:

<http://tsrc.berkeley.edu/sites/tsrc.berkeley.edu/files/San%20Diego%20Smart%20Parking%20Pilot%20COASTER%20Final%20Report.pdf>



The graph shows that as parking prices increase, more commuters will probably stop parking a car at a COASTER station. In the middle parking price range, the share of commuters "maybe" parking at a COASTER station grows and then decreases. As parking prices rise to relatively high levels, there is more certainty in commuter reactions.



Caltrans Division of Research,  
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# Research Results

Pavement

**MARCH 2013**

**Project Title:**

Mechanistic-Empirical Design—  
Phase Two: Implementation

**Task Number:** 1201

**Completion Date:** October 31, 2011

This task tested the effectiveness of the CalME and CalBack software tools, which use a mechanistic-empirical design approach to determine the best pavement solutions for rehabilitation, preservation, and building roads.

**Task Manager:**

Hamid Sadraie, Transportation Engineer,  
Office of Materials and Infrastructure  
[hamid.sadraie@dot.ca.gov](mailto:hamid.sadraie@dot.ca.gov)

## Implementing the Mechanistic-Empirical Pavement Design Method

*Improving pavement performance and cost efficiency using a more robust and complex design methodology*

### WHAT WAS THE NEED?

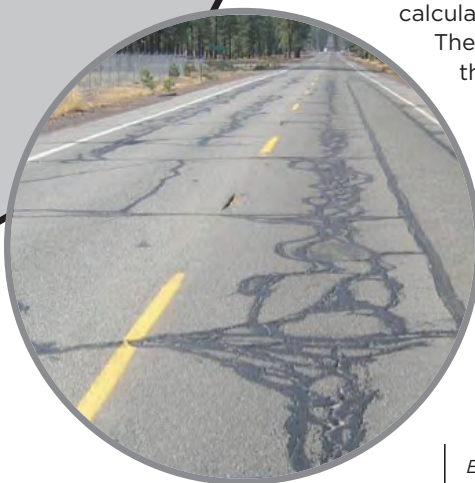
In the 1960s, Caltrans adopted methods to improve pavement design. Although these methods were innovative for their time, since then California roads handle far more traffic and heavier loads, and new materials for pavement construction, such as polymer- and nano-modified hot mix asphalt, have been introduced. Today, sustainable pavements that incorporate recycled materials and pavements with more adaptable structures are needed. However, the traditional pavement design method is not capable of integrating these new solutions or distinguishing cost-effective approaches for pavement rehabilitation, preservation, or new construction, because it can only analyze traffic load conditions, which does not provide enough information to understand the variations of a specific site.

In 2005, Caltrans, in partnership with the University of California Pavement Research Center, developed a mechanistic-empirical (ME) design method, a multistep process that uses detailed information about traffic loading, climate, material properties, and performance to gain a more detailed and accurate assessment of the specific project. The CalME and CalBack software tools can calculate deflections, strains, and stresses within the pavement structure.

The calculation results can also be used to assess the reliability of the design, helping to predict the probability of failure as well as determine the cause of failure.

### WHAT WAS OUR GOAL?

The goal was to implement the ME design method in the field and use the results from the investigations to analyze the effectiveness and use of the CalME and CalBack tools and refine the information-gathering techniques.



*Existing pavement, District 2,  
Plumas County, Route 36*



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research, developing innovations,  
and implementing solutions.

## WHAT DID WE DO?

Three typical rehabilitation projects were chosen to assess the ME analysis and design process:

- District 2, Plumas County, Route 36, PM 6.3 through 13.9
- District 1, Lake County, Route 53, PM 3.1 through 6.9
- District 6, Kings County, Route 198, PM 9.2 through 17.9

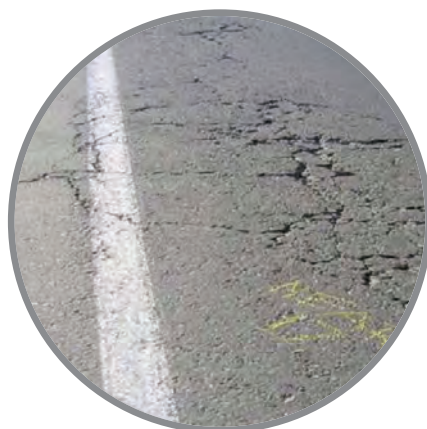
Caltrans, in partnership with the University of California Pavement Research Center, collected information about the condition of the existing pavements using various techniques, such as deflection testing, coring, material sampling, and condition assessment. The researchers calculated the stiffness of existing pavements with the CalBack software. They then performed the design process based on the condition of the existing pavement using both the traditional design method and the new CalME software and compared the results from these two methods.

## WHAT WAS THE OUTCOME?

The ME design method has the capability to recommend new, cost-effective rehabilitation designs that last longer. The traditional method cannot evaluate the same breadth of variables to take into account site-specific solutions. The ME design method accurately simulated the effects of the traffic levels and local climate. The ME approach examined the impact of different additives to concrete mixes to determine the best solution and avoid over-designing a project. The researchers were also able to perform a lifecycle cost analysis and select the most cost-effective choice among the new alternatives. For example, for one project, the ME analysis showed that by modifying the material being used, a 1-inch thinner layer could be applied to the pavement. Approximately \$1 million can be saved for every inch of reduced thickness for that specific project.

An analysis can also be rerun to evaluate the remaining service life of the as-built pavement. This information can be used in the pavement management system to estimate when future maintenance might be needed.

Alligator cracking,  
District 6,  
Kings County,  
Route 198



## WHAT IS THE BENEFIT?

Unlike the traditional design method, the Caltrans mechanistic-empirical design method can simulate the condition of existing pavement, the effects of climate, and the wear and tear of traffic levels and loads on the roads. With this information, innovative materials can be employed and new pavement structures designed for more cost-effective pavements with longer lifecycles.

## LEARN MORE

To view the complete reports for the projects:

[www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-01.pdf](http://www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-01.pdf)

[www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-02.pdf](http://www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-02.pdf)

[www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-03.pdf](http://www.ucprc.ucdavis.edu/PDF/UCPRC-TM-2008-03.pdf)



*The CalME tool can analyze the use of different materials in the context of climate and load inputs and determine the cost.*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Planning/  
Policy/  
System  
Information

**MARCH 2013**

**Project Title:**

Deployment Support and Data  
Collection for Caltrans TSI Travel  
Behavior Survey Using the GPS-ATD

**Task Number:** 2251

**Completion Date:** June 30, 2012

The Global Positioning System –  
Automated Travel Diary (GPS-ATD) allows  
agencies to collect data to understand  
the factors influencing personal travel  
behavior.

**Task Manager:**

Bradley Mizuno,  
Transportation Engineer, Electrical  
[bradley.mizuno@dot.ca.gov](mailto:bradley.mizuno@dot.ca.gov)

## GPS-Automated Travel Diary Enhances Travel Behavior Surveys

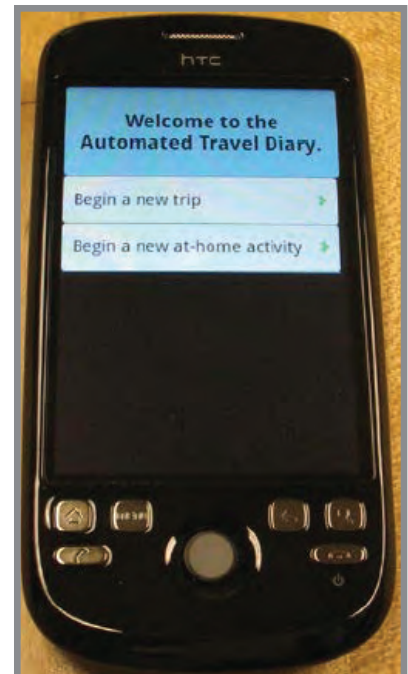
*New system allows analysts to measure the factors that influence  
personal travel behavior*

### WHAT WAS THE NEED?

Travel behavior surveys conducted by Caltrans and local state agencies have traditionally relied on participants using pen and paper diaries to collect data. Information, such as travel time, route choice, distance, and speed has generally been jotted down by individual survey participants who rely on memory and estimates. A real need existed for an automated, efficient, and affordable new comprehensive travel survey system. The ability to track short- and long-term mobility data is a critical part of developing accurate travel demand models, forecasting future demands, measuring trends in population behavior, and assessing the impact of changes in transportation policy or the transportation system.

### WHAT WAS OUR GOAL?

The project's objective was to develop and field test a new and reliable automated survey system to accurately capture day-to-day, even minute-by-minute, travel behavior, including trip purpose, travel mode, and traveler location, time, and speed. This project was intended to demonstrate the capability of smartphones to enhance travel behavior surveys.



GPS-ATD Android app



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and implementing solutions.



## WHAT DID WE DO?

In conjunction with Caltrans, UC Davis's Advanced Highway Maintenance & Construction Technology (AHMCT) Research Center, developed a prototype GPS Automated Travel Diary (GPS-ATD) to replace traditional pen and paper and computer-assisted approaches to travel surveys. Ten vehicular and 10 personal GPS-ATD units were produced and delivered for field testing.

With the increasing popularity of smartphones that have GPS capabilities, it was determined that developing the prototypes as originally envisioned was not as effective as using currently available technologies, so the focus shifted to developing a smartphone application (commonly called an app) instead. The GPS-ATD provides an intuitive user interface to capture trip activity information with minimum user input. The application captures and logs data from the GPS and internal sensors, minimizing user burden and errors in trip logs. During the development, the application was tested on multiple smartphone manufacturers across numerous versions of the Android operating system. About 400 trips were collected, with 80 respondents using 41 different devices with 27 unique Android models from all major U.S. wireless network carriers.

## WHAT WAS THE OUTCOME?

The GPS-ATD app was uploaded to the Google Play Store, and the source code is available for Caltrans and other public agencies. The app has been successfully tested on Android OS versions Donut through Gingerbread. Based on the test results, the AHMCT researchers are confident that the GPS-ATD app can run on any Android smartphone without modification.

## WHAT IS THE BENEFIT?

The Android app is easily modified for any survey and location-based data collection. Because of its advanced design, the app can provide many capabilities beyond previous methods in travel surveys. For example:

- Reduce the user burden by automating data collection and reducing data entry.
- Provide activity-time-space relationships.
- Minimize under-reported trips.
- Capture all transportation modes and mode changes.
- Provide strong support for automated data analysis.
- Provide vehicle position during GPS outages using inertial sensors.
- Capture second-by-second detailed vehicle position, speed, and acceleration.
- Provide wireless synchronization.

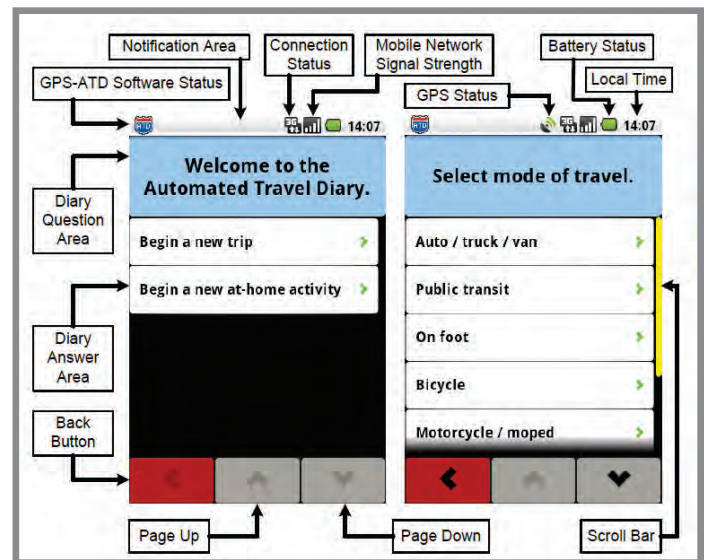
## LEARN MORE

To view the report:

<http://ahmct.ucdavis.edu/pdf/UCD-ARR-11-10-31-02.pdf>

For more information, visit the AHMCT website:

<http://ahmct.ucdavis.edu/?projects=automated-travel-diary>



Sample user interface of the  
GPS-ATD Android app





Caltrans Division of Research,  
Innovation and System Information

# Research Results

Planning/  
Policy/  
System  
Information

**MARCH 2013**

**Project Title:**

Measuring and Modeling Particulate Matter Emissions from Heavy-Duty Construction Equipment

**Task Number:** 1204

**Completion Date:** June 30, 2012

This project developed a model to measure particulate matter emissions from heavy equipment to address the environmental impact of Caltrans' construction activities and meet regulatory requirements.

**Task Manager:**

Patrick Tyner,  
Associate Transportation Planner  
[Patrick.Tyner@dot.ca.gov](mailto:Patrick.Tyner@dot.ca.gov)

## Measuring the Particulate Matter Emissions of Construction Equipment

*Developing a model for gathering emissions data to address regulatory air requirements*

### WHAT WAS THE NEED?

The gaseous and particulate matter emissions from construction engines are an important portion of total air pollutants, and they are drawing increasing regulatory attention. To assess the contribution of construction equipment, such as that used by Caltrans for projects in non-attainment or maintenance areas, it is necessary to quantify the nitrogen oxide and particulate matter emissions. Currently, no model for estimating construction emissions or the development of appropriate regulations has been mutually accepted by Caltrans and regulatory agencies. This situation is due in part to a lack of emissions data from construction equipment while it is in use. The results of this research will provide scientific-based validation of emissions regarding the environmental impact of Caltrans' construction activities, thereby reducing project costs, improving air quality, and promoting public health.

### WHAT WAS OUR GOAL?

The goal of this research was to obtain quantitative particulate matter data on heavy-duty construction equipment and develop a model to estimate gaseous and particulate matter emissions to address environmental regulatory concerns.



*Measuring the emissions of a backhoe*



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## WHAT DID WE DO?

The focus of this task was on particulate matter emissions for which there are no commercially available instruments for use in the field. Caltrans, in partnership with the UC Riverside Center for Environmental Research and Technology (CE-CERT), took emissions measurements for seven in-use pieces of construction equipment. The equipment included four backhoes and three wheel loaders. Over the course of the test program, two different analyzers were used to gather emissions data. One analyzer measured all gaseous species, and the other measured the particulate matter. In-field emissions measurements were made on a second-by-second basis using a portable emissions measurement system to develop relationships between nitrogen oxides, particulate matter, and other emissions and fuel use. This program used instrumentation that is being developed at UC Riverside and expanded it to include particulate matter emissions.

## WHAT WAS THE OUTCOME?

Most construction equipment of approximately the same size exhibited similar emission profiles. Differences between cold-start and warm-start idle emissions among the different equipment were observed. Normalizing emission output by fuel resulted in relatively small variations in emission levels under different levels of load. When the data collection effort was nearing completion, it was determined that a second phase task was needed to develop an Excel-based air emissions model to analyze collected emissions datasets. The task would focus primarily on particulate matter emissions because this evaluation gap needs to be closed.



*The UC Riverside mobile emissions laboratory (MEL) is a unique laboratory containing all the instrumentation normally found in a conventional vehicle emissions laboratory but mounted inside a 53-foot truck trailer.*

## WHAT IS THE BENEFIT?

As emissions and activity data become available for other equipment types, the emissions model can be modified so that it can have wide applicability and provide a formal basis for regulatory development. A more efficient regulatory process will allow more rapid adoption of regulations that will improve air quality and promote public health, while reducing legal costs and project delays. The emissions data gathered through this effort will be used to develop a model to determine emissions from different types of construction equipment or for construction projects as a whole. The model will be a user-friendly program based in Excel that can be readily used by program staff at Caltrans, outside contractors, or other government agencies.

## LEARN MORE

To view the full report:

[www.dot.ca.gov/research/researchreports/reports/2012/2012-01\\_task\\_1204\\_ppsi.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-01_task_1204_ppsi.pdf)



*Measuring the emissions of a wheel loader at a quarry in Thermal, California*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Planning/  
Policy/  
System  
Information

**MARCH 2013**

**Project Title:**  
Sustainable Transportation Energy  
Pathways (STEPS)

**Task Number:** 1537  
**Completion Date:** October 31, 2011

This high-profile, publicly and privately supported project addresses the need to develop new theory, tools, and methods that allow for transparent comparisons of promising alternative energy models and creative vehicle solutions to help Caltrans determine their potential benefits in its own fleet and beyond, as well as further the goal of greener and more environmentally-responsible business practices.

**Project Manager:**  
Patrick Tyner, Associate  
Transportation Planner  
[Patrick.Tyner@dot.ca.gov](mailto:Patrick.Tyner@dot.ca.gov)

## Sustainable Transportation Energy Pathways (STEPS)

*Hydrogen, biofuels, electricity, and fossil fuels are the four fuel pathways at the core of the STEPS research*

### WHAT WAS THE NEED?

Global demand for transportation mobility is exploding, particularly in the developing world where the number of vehicles on the road increases five to six percent every year. Worldwide, this number is projected to triple by the year 2050, according to the International Energy Agency (IEA). Energy supply is a critical concern, especially for the transportation sector. Over the last century, our transportation system has been based almost exclusively on petroleum and the internal combustion engine. With the cost of conventional crude oil rising, and petroleum substitutes, including unconventional oil from shale and tar sands, facing economic, technical, and environmental challenges, vehicles powered by alternative energy sources are in more demand than ever before.

A variety of high-efficiency vehicles, including those with hybrid drive trains and fuel cells along with battery electric vehicles, as well as new fuels, such as compressed natural gas, ethanol, methanol, dimethyl ether, Fischer-Tropsch process diesel, electricity, and hydrogen, are now securely on the table as potential solutions to address climate change, energy supply, and security concerns. Government and industry are seeking solutions and effective transition strategies for a sustainable transportation future.

### WHAT WAS OUR GOAL?

The project's goal was to inform public debate on alternative energies and vehicles, form and work with a consortium of public-private sponsors, explore transportation alternatives, develop and apply theory, tools, methods, and research data in comparative assessments focusing on four general transportation energy pathways: hydrogen, biofuels, electricity, and fossil fuels.



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## WHAT DID WE DO?

Over the course of four years, STEPS researchers conducted impartial, comparative analyses of alternative fuel and vehicle pathways. Using an interdisciplinary approach, they drew on engineering, economics, environmental science, and consumer behavior to inform their industrial and government sponsors about the cost-benefit potential of the four transportation energy pathways identified for this project. They explored the technical aspects, costs, market issues, environmental implications, and transition issues for each individual pathway.

Analyzing single-fuel pathways provided a strong basis for comparing different fuels and developing scenarios for how the fuel/vehicle pathways might be integrated to meet society's goals. The research flowed naturally from single pathway analyses to robust comparisons of fuel pathways; then to integrative scenarios and transition analyses for future vehicles and fuels; and finally, to case studies to inform carbon and alternative fuel policies in California, the United States, and beyond in the interest of reducing greenhouse gas emissions and oil dependency.

## WHAT WAS THE OUTCOME?

As STEPS researchers assessed the prospects and compared the characteristics, costs and benefits for alternative vehicles and fuels (biofuels, electricity, and hydrogen), new scenarios began taking shape detailing how these future technologies might transform the transportation sector and what policies would need to be implemented to support this complex transition over the next few decades.

Achieving aggressive targets for sustainable transportation requires a portfolio approach that combines new vehicle and fuel technologies, behavioral changes, and newly crafted policies. One new policy instrument, known as a low-carbon fuel standard (LCFS), could be a promising approach to getting the carbon out of fuels if it inspires industry to pursue innovation aggressively and is flexible and performance-based. Just one idea of many, strategies within this portfolio are expected to vary widely from region to region.

Key results for the STEPS program include:

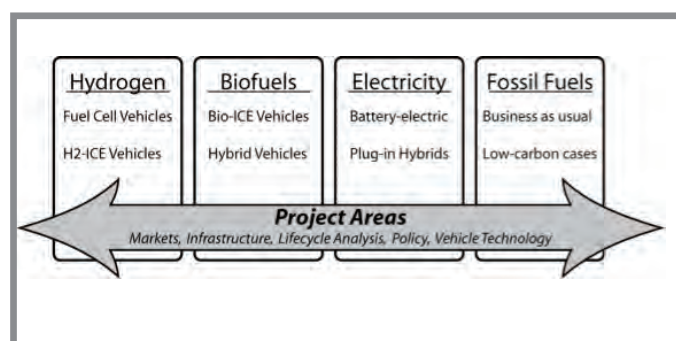
- Over 130 books, chapters, and major journal articles and numerous research reports published
- Completion of more than 30 research projects
- Twelve symposia, consortium meetings, and policymaker outreach events
- Publication of *Sustainable Transportation Energy Pathways: a Research Summary for Decision Makers*, edited by Joan Ogden and Lorraine Anderson, UC Davis Institute of Transportation Studies—the core publication that summarizes the lessons learned from the STEPS project

## WHAT IS THE BENEFIT?

Caltrans will distribute the STEPS program results for management decision-making and policy development for future activities concerning alternative fuel usage and transportation and environmental sustainability. This research will allow Caltrans to determine the potential benefits of all alternative fuel types in its own vehicle and equipment fleet and further the goal of promoting and utilizing cleaner fuels in support of greener and more environmentally-responsible business practices.

## LEARN MORE

For more about the STEPS book, *Sustainable Transportation Energy Pathways: A Research Summary for Decision Makers*, see <http://steps.ucdavis.edu/STEPS.Book>



*Sustainable Transportation Energy Pathways (STEPS) research is organized around these four fuel pathways.*





Caltrans Division of Research,  
Innovation and System Information

# Research Results

Right of Way/  
Land Surveys

**MARCH 2013**

**Project Title:**

Field Use of 3D Terrestrial Laser Scanning on Caltrans Projects

**Task Number:** 2056

**Completion Date:** June 30, 2012

This project applied 3D terrestrial laser scanning standards and workflows in transportation case studies and field use to accelerate project delivery, improve quality, and enhance safety for Caltrans operations.

**Task Manager:**

Arvern Lofton,  
Transportation Engineer, Electrical  
[alofton@dot.ca.gov](mailto:alofton@dot.ca.gov)

## 3D Terrestrial Laser Scanning

*Using highly accurate and safer 3D ground-based laser scanners for surveying pavements, bridge structures, and roadways*

### WHAT WAS THE NEED?

Terrestrial laser scanners (TLS) are a new class of survey instruments that are increasingly used in providing modeling data for various applications, including land surveying, architecture, bridge structures, and highway construction. These ground-based 3D scanners use advanced laser measurement technology capable of obtaining thousands of point measurements per second. They generate a highly detailed data set, which can then be used to create an accurate and comprehensive 3D Computer-Aided Design (CAD) model.

The 3D laser scanners provide surveyors data that would otherwise be difficult or impossible to measure using traditional surveying instruments. In the traditional survey process, surveyors, particularly the rod person, are often exposed to a variety of environmental hazards, including walking across roadways with high-speed traffic, climbing steep slopes, and standing close to traffic.

Other transportation departments and private contractors have used laser scanning in highway survey applications and found that it reduces the need for lane closures, decreases the risk of injuries, and increases productivity. The resulting detailed 3D model allows engineers and surveyors to extract all the required data in the office, decreasing or eliminating the need for surveyors to return to the site for additional measurements.

### WHAT WAS OUR GOAL?

The project's objective was to perform case studies of field applications using fixed 3D laser scanners to analyze their applicability, costs, and benefits for surveying pavements, bridge structures, roadside assets, and other Caltrans application areas, in addition to developing best practices and workflows and providing operator training.



*Caltrans District 11 crew surveys the Highway 805 and 905 interchange using a ScanStation 2 laser scanner during training.*



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## WHAT DID WE DO?

UC Davis's Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, in partnership with the Caltrans Office of Land Surveys, did the following:

- Field tested, operated, and collected data using 3D terrestrial laser scanners
- Developed best practices and workflows for implementing 3D terrestrial laser scanners
- Provided TLS training for Caltrans survey crews from several districts
- Produced in-depth material to support future Caltrans training, deployment, and on-going use of 3D laser scanning
- Documented how to plan and scan field work, set up scanner and troubleshoot, and process the collected data

## WHAT WAS THE OUTCOME?

Caltrans has successfully deployed the new TLS technology for its surveyors. It has acquired its own TLS systems and is using them as part of its regular surveying operations. Compared to traditional survey instruments, which are limited to locating one point at a time and can only measure up to eight distances per second, the 3D laser scanners are capable of measuring, as of this research, up to 50,000 distances per second, with the speeds increasing for emerging commercial systems.

Well-trained survey personnel are capable of applying fixed 3D terrestrial laser scanning using Caltrans-specific workflows for efficient and consistent results. The collected high-accuracy, feature-rich data allow users to generate surveys on demand by extracting the desired features and attributes, without having to return to the field for measurements. Engineers can obtain model information, such as relative angle and length dimensions, from the resulting 3D surface CAD model.



*Night scanning of the old Bay Bridge for the design and construction of the new Bay Bridge detour in District 4*

## WHAT IS THE BENEFIT?

The 3D ground-based laser scanners accelerate project delivery and improve the quality and efficiency of Caltrans operations. The collected data can be stored and reused on demand. The technology allows operators to set up the equipment in a more convenient location, reducing lane closures and enhancing the safety of survey teams.

## LEARN MORE

To view the report:

<http://ahmct.ucdavis.edu/pdf/UCD-ARR-09-02-28-02.pdf>



*ScanStation 2 laser scanner in action during field-work training in District 2*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Rural

**MARCH 2013**

**Project Title:**

Evaluation of an Animal Warning  
System Effectiveness, Phase Two

**Task Number:** 2090

**Completion Date:** June 30, 2012

This project focused on studying the effectiveness of using animal warning systems to detect wildlife on roadsides, including measuring drivers' response to the associated animal warning signs.

**Task Manager:**

Nathan Loebis,  
Transportation Engineer, Electrical  
[Nathan\\_Loebis@dot.ca.gov](mailto:Nathan_Loebis@dot.ca.gov)

## Wildlife on the Roadside: Testing PATH's Animal Warning System

*Prototype system uses break-a-beam microwave technology to detect large animals*

### WHAT WAS THE NEED?

Recent data shows that more than 300,000 vehicular collisions with large animals occur every year, resulting in 29,000 human injuries, 211 fatalities, and \$1 billion in property damage. These numbers are climbing steadily and are thought to be only a fraction of the actual occurrences, as many such collisions go unreported. In response, a variety of crash-reduction solutions have been discussed, from fencing and flashing systems to animal repellants and whistles. While some prototype systems have been installed in the past few years, very little long-term data exists.

### WHAT WAS OUR GOAL?

The project's goal was to evaluate the effectiveness of animal warning systems to detect wildlife on roadsides and measure driver response, including speed reduction and other driver behaviors.



*Installation of an animal warning sign*



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research, developing innovations,  
and implementing solutions.

## WHAT DID WE DO?

In September 2009, Caltrans—with supporting funds from the US Department of Transportation—installed the Partners for Advanced Transportation Technology (PATH) Animal Warning System (PAWS) along a 0.6 mile stretch of State Route 3 near Fort Jones in the Scott Valley area of Siskiyou County, one of the highest black-tailed deer kill areas in the state. PAWS uses microwave beams to detect the appearance of large animals. Animal motion through these beams triggers a transmission that illuminates warning signs on both sides of the roadside.

During the first 2.5 months of the 10-month field study, initial baseline data was collected with the warning signs covered. Throughout the remaining 7.5 months, the warning signs were in full view, and animal detection events, vehicle speeds, and warning sign activation activities were logged. Radar, video, and computer equipment monitored driver reaction via the PAWS Monitoring System and PAWS Data Acquisition System designed for this project. In addition, driver feedback was collected in a follow-up survey.

## WHAT WAS THE OUTCOME?

While animal detection systems are largely experimental, associated studies suggest that they can result in lower vehicle speeds and substantial reduction in animal-vehicle collisions. The PAWS study—designed as a research prototype—was intended to show the feasibility of these systems.

This project's results did show a reduction in average driving speeds when animal warning signs were illuminated, which was greatest during evening, overnight, and early morning hours, times when deer and other wildlife tend to be most active. Additional data suggests that the deceleration rates that were required when drivers spotted an animal were also reduced, mitigating the need for panic stops. No evidence was seen suggesting driver adaptation to the PAWS signs over the duration of the study.

*Break-a-beam microwave devices at the Northern California test site. Three are installed on each side of the road.*



However, driver survey data indicated that most respondents were unhappy with the system, detailing driver concerns over system costs, the brightness of the signs after dark, and site location.

Based on a high number of perceived false positives, surveyed drivers expressed low confidence in the system's reliability. In actuality, a majority of the false animal detections were related to vehicles turning on and off the road, a limitation researchers know must be overcome to regain the public's confidence. In the end, the system was not accepted by the public or the district in which it was tested. Caltrans is in the process of having it dismantled and removed.

Study analysts note that the State Route 3 system might have been more reliable had specific modifications been put in place. Animal detection systems are still considered experimental, and reliability issues will need to be addressed. Only then will it be clear whether implementation of these systems can be considered an alternative to the more expensive wildlife fencing in combination with wildlife underpasses and overpasses.

## WHAT IS THE BENEFIT?

Long-term experience and data are needed regarding reliable animal warning effectiveness. The PAWS study provides information to state agencies that are considering selecting reliable off-the-shelf systems to reduce crashes and improve transportation safety. PAWS data could also lead to the development of improved warning systems that alert drivers of impending road hazards. Studies have shown that dynamic situational information is more reliable in catching a driver's attention than any other current system.

The ultimate goal is to increase road safety for the public, reduce costs caused by wildlife-vehicle collisions and reduce wildlife road kill, while allowing animals to continue to move across the landscape. Animal detection systems remain a compelling and potentially effective countermeasure to large animal-vehicle crashes, providing both a sensing and dynamic situational warning. This study adds valuable data to the animal warning system portfolio.

## LEARN MORE

To view the report:  
[www.dot.ca.gov/research/researchreports/reports/2012/2012-06\\_task\\_2090-tsm.pdf](http://www.dot.ca.gov/research/researchreports/reports/2012/2012-06_task_2090-tsm.pdf)

## Seismic

**MARCH 2013**

**Project Title:**

Bridge Design for Earthquake Fault Crossings: Synthesis of Design Issues and Strategies

**Task Number:** 2177

**Completion Date:** May 31, 2012

This project verified the reliability of the Fault Rupture-Response Spectrum Analysis and Fault Rupture-Linear Static Analysis methods to estimate the displacement responses of curved bridges.

**Task Manager:**

Allaoua Kartoum,  
Transportation Engineer  
[allaoua.kartoum@dot.ca.gov](mailto:allaoua.kartoum@dot.ca.gov)

## Designing Bridges Crossing Earthquake Faults

*Developing practical analysis procedures to estimate bridge rupture response to seismic activity*

### WHAT WAS THE NEED?

Bridges that cross earthquake faults can be more vulnerable to damage than those located on one side of the earthquake fault. Although avoiding building bridges across earthquake fault zones might be the best design strategy, it is not always possible to do so in regions of high seismicity, such as California. Response History Analysis (RHA), a rigorous nonlinear method that uses spatially varying ground motions based on site-specific seismological studies, can be conducted, but this procedure typically requires extensive modeling and computational efforts, making it less practical for bridge engineers.

In response to the absence of practical analysis methods for bridges crossing fault rupture zones, a previous Caltrans study developed and validated two simplified procedures, Fault Rupture-Response Spectrum Analysis (FR-RSA) and Fault Rupture-Linear Static Analysis (FR-LSA), as alternatives to the exacting Response History Analysis (RHA) approach. The initial validation of these procedures was performed on ordinary straight bridges. However, a significant number of California bridges have features that differ from those that were tested. Further evaluation of the adequacy of the simplified analysis procedures is urgently needed in the context of representative actual bridges, particularly curved bridges. In addition, a critical knowledge gap exists in implementing the approximate procedures in practical design.

### WHAT WAS OUR GOAL?

The goal was to verify the reliability of simplified procedures to estimate the displacement responses for curved bridges that cross earthquake faults and to document the results for Caltrans Seismic Design Criteria.



*Selected three-span bridge*



## WHAT DID WE DO?

Caltrans, in partnership with the California Polytechnic State University College of Engineering, selected two curved bridges—three-span and four-span—that represent typical California construction. The selected bridges were assumed to cross strike-slip fault ruptures. Numerical models of the selected bridges were developed using Open System for Earthquake Engineering Simulation (OpenSees). The adequacy of the FR-RSA and FR-LSA procedures was then examined by comparing the results with the more rigorous RHA procedure. A set of 10 ground motion records, which include a relative fault offset of 100 cm, were used in this investigation.

The ground offset was determined to place bridge bents well into the inelastic range while not so large as to completely dominate the contribution of the dynamic response. The bridge displacement response quantities extracted for validation purposes included abutment longitudinal displacement, abutment transverse displacement, and resultant bent drift. Other parameters considered in the numerical models and varied in the analysis include abutment longitudinal stiffness, bridge-to-fault angles, and fault locations.

## WHAT WAS THE OUTCOME?

The research produced the following results based on the numerical simulations conducted:

- Analysis results from both three-span and four-span bridges demonstrated that the quasi-static response alone, which is caused only by ground displacement offset, is inadequate in estimating the bridge response.

- The FR-RSA procedure consistently provides reasonable demand estimates in all considered cases accounting for different numbers of bents, longitudinal abutment stiffness values, fault locations, and fault-to-bridge angles. The results are close enough to those from the RHA method for representative curved bridges crossing fault ruptures.
- The FR-LSA method provides reasonable results for the three-span bridge, but predicts overly conservative demand estimates for the four-span bridge. Therefore, it is suggested that FR-LSA be used with caution for bridges with more than three spans.

## WHAT IS THE BENEFIT?

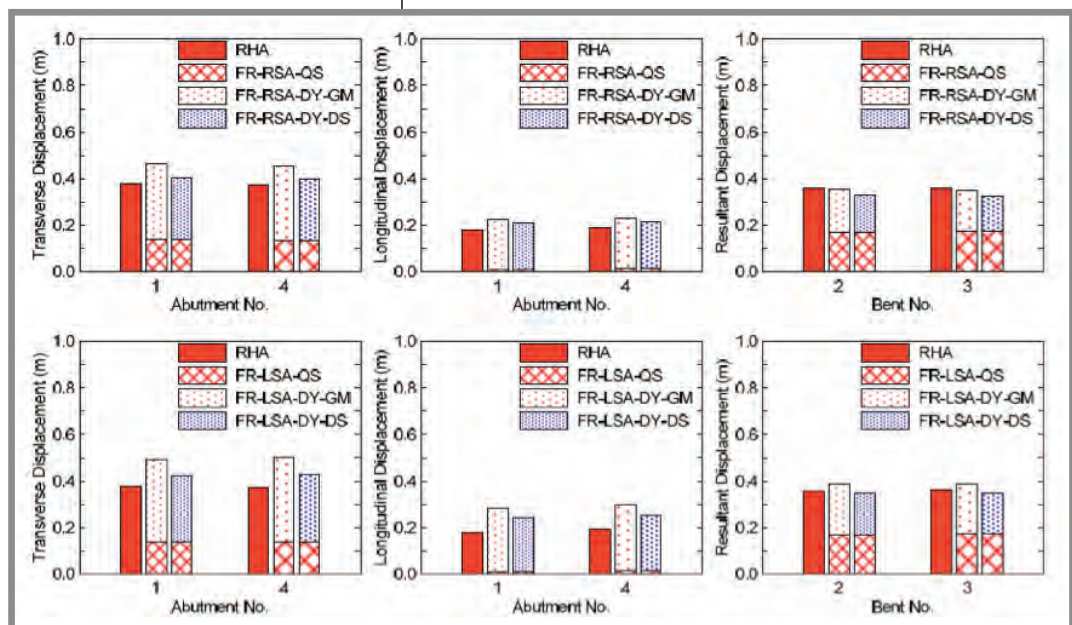
Based on the results from this investigation, the simplified FR-RSA procedure can be used as an alternative to the nonlinear RHA with multiple support excitation. FR-RSA implemented on CSiBridge provides adequate predictions for bridge responses and can be used in future practice.

## LEARN MORE

To view the full report:

[www.dot.ca.gov/hq/esc/earthquake\\_engineering/Research\\_Reports/vendor/cal\\_poly/65A0379Final\\_Report.pdf](http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research_Reports/vendor/cal_poly/65A0379Final_Report.pdf)

*Typical OpenSees  
result comparisons:  
RHA vs. FR-RSA and  
RHA vs. FR-LSA*







Caltrans Division of Research,  
Innovation and System Information

# Research Results

Seismic

**MARCH 2013**

**Project Title:**

Full-Scale Seismic Performance  
Testing of U.S. Highway Bridge Column

**Task Number:** TPF-5 (180), Task 1731

This collaborative project tested a 24-foot tall bridge column built to current Caltrans design standards on a high-performance shake table. As the first column ever tested in the U.S. at full scale under dynamic loading conditions, this test serves as a benchmark for smaller-scale future testing.

**Task Manager:**

Mike Keever, Chief,  
Office of Earthquake Engineering  
[mike\\_keeve@dot.ca.gov](mailto:mike_keeve@dot.ca.gov)

## Caltrans Bridge Column Demonstrates Resilience in Full-Scale Seismic Test

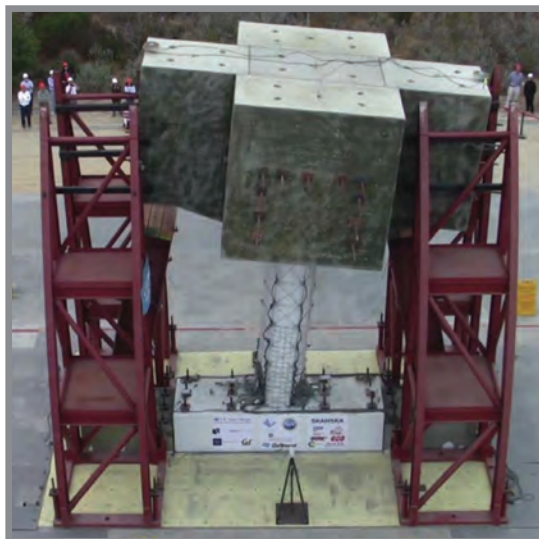
*Ductile column design allows for controlled damage while maintaining load-carrying capacity*

### WHAT WAS THE NEED?

Ensuring the seismic resilience of a bridge during and after a major earthquake is of paramount importance to Caltrans. Bridge columns carry the weight of the bridge itself plus the traffic flowing over it, and therefore must be designed to withstand extreme earthquake shaking loads. The Caltrans ductile column design—based on design principles introduced in the 1970s—allows for controlled damage of bridge columns without sacrificing load-carrying capacity. Decades of research experiments have tested and proven the integrity of the ductile design principles, but these experiments were conducted on small-scale specimens or under static loading conditions. Only recently has sufficiently powerful testing equipment become available to test these fundamental seismic-design principles at full scale under dynamic conditions.

### WHAT WAS OUR GOAL?

The project's objective was to validate Caltrans' modern seismic design codes for bridge columns and provide benchmark, full-scale test results for evaluating and calibrating past and future experiments conducted at reduced scale or under static loading conditions.



*Beaten, but not broken, a full-scale Caltrans-designed bridge column on the UCSD/NEES Outdoor Shake Table maintains vertical support of more than 260 tons after undergoing six simulated earthquakes, each in excess of maximum design load.*



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## WHAT DID WE DO?

Testing occurred at the UC San Diego Network for Earthquake Engineering Simulation Large High Performance Outdoor Shake Table facility, the largest shake table in the country. The full-scale column test specimen were 24-feet high with a 4-foot diameter, weighing 24 tons. A concrete mass of more than 260 tons was added to simulate the contributing weight of a loaded bridge superstructure. The column was attached to the shake table through an elongated foundation detailed to have representative performance in the direction of motion. For safety, a standalone steel catcher frame was built around the specimen to prevent catastrophic collapse.

The testing protocol consisted of two series of earthquakes: an initial series of six earthquakes intended to drive the column through a controlled series of damage states beyond Caltrans design standard, and an extended set of repeated extreme motions intended to force the column through even higher damage states. The selection and scaling of these earthquake motions were closely reviewed by Caltrans ground-motion experts to ensure that shaking levels would exercise the full range of design-level loads anticipated within California.

This research is a key component of a collaborative long-term program conducted by Caltrans, the Federal Highway Administration (FHWA), Pacific Earthquake Engineering Research Center (PEER), the National Science Foundation (NSF), and international partners in Japan. Project planning through the Transportation Pooled Fund (TPF) program began in 2008 and was finalized in 2010.

## WHAT WAS THE OUTCOME?

The first US-design-based column ever tested at full scale under dynamic loading conditions, this test demonstrated excellent performance that fully validates Caltrans seismic design codes for bridge columns. The results for design-level loading show that column damage occurred in the fuse location near the column base, as per design, and was largely limited to spalling of cover concrete with minor signs of initial buckling of reinforcing bars. This performance was better than anticipated or required.

A series of six additional earthquakes at substantially higher-than-design loading was required to induce ultimate collapse. Here, collapse was defined as the test specimen making contact with the safety frame during dynamic loading. Column performance under these multiple cycles of extreme loading was also better than anticipated or required. Even with the complete rupture of several longitudinal reinforcing bars, the column was capable of supporting the full 260-ton load under static conditions. This test will serve as a benchmark for interpretation of smaller-scale tests.

## WHAT IS THE BENEFIT?

These results indicate that Caltrans seismic design standards for a modern ductile column meet and exceed design requirements and should be retained. These findings validate the seismic design principles already embodied in Caltrans Seismic Design Criteria (SDC) and Bridge Design Specifications (BDS).

## LEARN MORE

For information about the Outdoor Shake Table:  
<http://nees.ucsd.edu/facilities>

To view a test cycle:  
[www.youtube.com/watch?v=uF8Fy9KAlis&feature=player\\_embedded](http://www.youtube.com/watch?v=uF8Fy9KAlis&feature=player_embedded)



*Close-up view of ductile fuse at column base after completion of all testing*



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Seismic

**MARCH 2013**

**Project Title:**

Rapid Construction of Bridge Piers  
with Improved Seismic Performance

**Task Number:** 1972

**Completion Date:** September 30, 2012

This project investigated the performance of concrete-filled tube (CFT) columns for bridge construction and developed designs for simple and economical column-to-footing connections.

**Task Manager:**

Peter Lee,  
Research Contract Manager  
[peter.s.lee@dot.ca.gov](mailto:peter.s.lee@dot.ca.gov)

## Constructing Bridge Piers More Rapidly with Improved Seismic Performance

*Using concrete-filled tube columns for bridge piers to reduce construction time, lower costs, and enhance seismic performance*

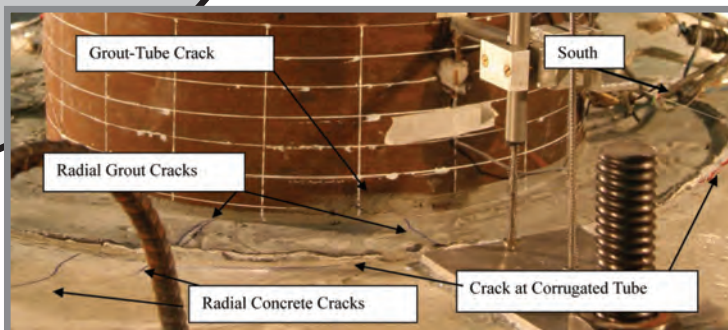
### WHAT WAS THE NEED?

Bridge construction requires practical methods that allow for rapid and efficient construction. When construction proceeds slowly, costs increase, traffic and commerce are interrupted, and workers are exposed to greater risk of injury. In high-seismic areas, adherence to strict engineering performance requirements must also be considered. Concrete-filled tube (CFT) bridge piers can meet these diverse requirements.

CFTs not only promote economical and rapid construction, but also offer increased strength and stiffness compared to structural steel and reinforced concrete, allowing smaller sections to be used. CFTs eliminate the time and costs associated with column formwork and reinforcing cage construction. They can also employ modern, self-consolidating concretes, further reducing labor and construction time.

CFT components encourage the optimal behavior of the concrete and steel. The steel tube serves as formwork and reinforcement to the concrete fill. The fill increases the compressive strength and stiffness, delays and restrains local buckling of the tube, and enhances ductility and resistance if composite action is achieved. The concrete inside the tube is protected from the

environment. Although CFTs offer many practical advantages, few studies have focused on the connections for CFT columns to the footings or cap beams, a critical element of bridge construction. This research investigated and developed design procedures for simple and economical connections of circular CFT piers or columns to reinforced concrete foundations, pile caps, and wide cap beams.



*Crack formations on south side of specimens*



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## WHAT WAS OUR GOAL?

The goal of this research is to reduce construction time and improve seismic structural performance by exploring the potential of CFT column construction for bridge piers and develop an efficient and effective column-to-footing connection.

## WHAT DID WE DO?

The Caltrans Division of Engineering Services, in partnership with the University of Washington Department of Civil and Environmental Engineering, investigated the seismic performance of a new type of bridge pier system constructed using spiral weld steel tubes filled with a low-shrinkage concrete. The research used experimental methods to investigate salient parameters, including the diameter-to-thickness ratio of the steel tube, embedment depth of the steel tube into the adjacent concrete component (foundation element or cap beam), and the type of steel tube. The information was used to develop design expressions for the connection, flexural strength and stiffness, and geometric constraints of the system.

The researchers developed design procedures for simple and economical connections of circular CFT piers to reinforced concrete foundations, pile caps, and wide cap beams. The connection requires no dowels or internal reinforcement to connect the tube to the footing or cap beam. The connection uses an annular ring that is welded to

the base of the tube. The ring tube is placed into a void in the concrete footing, which is formed using a corrugated steel pipe. The void between the tube and pipe is filled with a high-strength fiber-reinforced grout. The tube is then filled with a low-shrinkage concrete. The seismic performance of the CFT column and connection assembly was compared to a conventional reinforced concrete column.

## WHAT WAS THE OUTCOME?

The research showed that the proposed connection develops the full capacity of the composite column, provides excellent ductility, and inelastic deformation capacity under seismic loading while mitigating damage at larger drift demands than the reinforced concrete column.

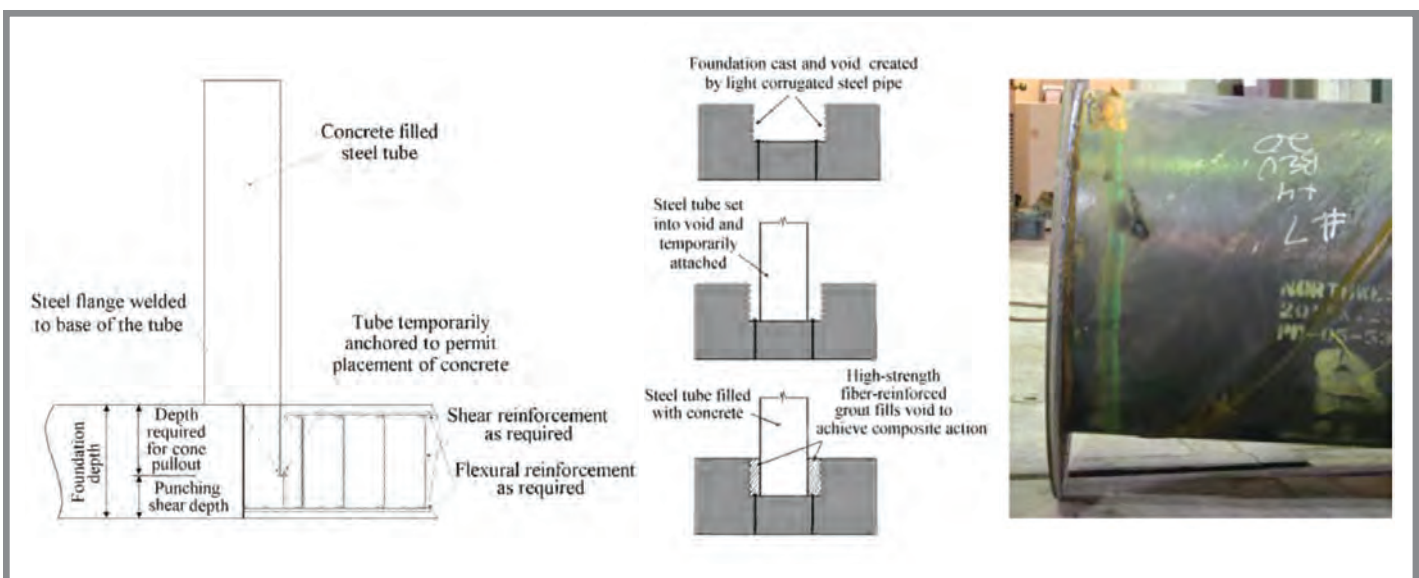
## WHAT IS THE BENEFIT?

CFTs can meet or exceed seismic performance criteria. In addition, they lend themselves to rapid construction and reduced column sizes. As a result, smaller columns can be constructed cheaper and quicker. This is especially important for urban areas such as in Southern California.

## LEARN MORE

To view the full report:

[www.dot.ca.gov/hq/esc/earthquake\\_engineering/Research\\_Reports/vendor/washington/Final%20Report%20CA12-1972%2059A0641.pdf](http://www.dot.ca.gov/hq/esc/earthquake_engineering/Research_Reports/vendor/washington/Final%20Report%20CA12-1972%2059A0641.pdf)



*Construction of a CFT column and connection:*

*(l) Overall configuration; (c) Construction procedure for grouted connection; (r) Welded annular ring at base of tube*



Caltrans Division of Research,  
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# Research Results

Transportation  
Safety and  
Mobility

**MARCH 2013**

**Project Title:**

Crash Attenuator Usage Along  
Travelways and in Work Zones

**Task Number:** 1739

**Completion Date:** June 30, 2012

This project developed a method for evaluating the lifecycle costs for highway crash attenuators by considering purchase and repair costs, accessibility, and frequency of impact to provide traffic designers a means to identify the most cost-effective product for a given site.

**Task Manager:**

Vue Her, Project Manager,  
Transportation Engineer  
[vue.her@dot.ca.gov](mailto:vue.her@dot.ca.gov)

## Crash Attenuator Usage Along Highways

*Methodology for evaluating site suitability and long-term costs of crash attenuators*

### WHAT WAS THE NEED?

Crash attenuators are installed along roadways to help protect motorists. They are designed to safely decelerate or redirect a vehicle and reduce the risk to the vehicle's occupants and other nearby vehicles. All attenuators must meet federal safety standards and be approved by Caltrans. The requirements for approval are based on crash tests and the crash effects on vehicle occupants. No consideration is given to the durability of the attenuator after impact and the associated costs.

Crash attenuators offer different levels of performance and have a wide range of costs, up to \$60,000 per installation. Attenuators are designed to be hit, so repairs must be considered as part of the overall cost. Repair costs fluctuate greatly based on the type of impact and how accessible the location is.

After being hit, attenuators can be either removed (sacrificed) or repaired. Restoring a crash attenuator can require multiple trips, starting with an inspection to assess the damage and the parts needed. Subsequent trips might require crews to control traffic to complete the work. A new class of attenuators that are easier to reset in place cost more upfront but are less expensive to maintain. The cost-effectiveness of these resettable class attenuators is often overlooked with the current focus on initial costs rather than long-term upkeep.

### WHAT WAS OUR GOAL?

The goal of this research was to develop a methodology for comparing the lifecycle costs of highway crash attenuators to identify which product is best for a given site based on accessibility, frequency of impact, initial costs, and ongoing repairs.



Protection at exit ramp



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## WHAT DID WE DO?

Caltrans, in partnership with UC Davis's Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, met with district maintenance and design staff to develop a methodology for selecting crash attenuators for a specific location by assessing various factors. The performance of different attenuators was reviewed and classified based on the typical repairs needed after impact. The researchers developed a formula to help quantify the value of specific attenuator features, a location's accessibility for repair crews, repair costs, and other variables associated with the likelihood or frequency of impacts.

## WHAT WAS THE OUTCOME?

This research determined that two of the most important site attributes influencing lifecycle costs of crash attenuators are the expected frequency of impact and the access factor—how difficult it is for crews to access the particular location to make repairs. For highway sites with elevated values of either of these factors, in-service maintenance costs are the most important consideration, and products designed for cost-effective reset or repair are preferred. The research also identified a class of severe-duty attenuators that can be reset by crews after impact with few or no repairs or replacement parts.

The results of this methodology are applicable to other agencies responsible for designing and maintaining crash attenuators. Additional data on repair costs and the type of impacts most frequently seen will enhance the accuracy of the model.

## WHAT IS THE BENEFIT?

Substantial savings can be realized by analyzing the lifecycle costs of crash attenuators and choosing the appropriate product for the site. Some sites can use a less expensive attenuator because few incidents occur. For those sites that are difficult to access and experience frequent collisions, installing a more robust attenuator would cost more initially but reduce maintenance costs in the long term. Systematically evaluating the location might also reveal that a sacrificial product could be more appropriate and cost-effective.

## LEARN MORE

To view the full report:

<http://ahmct.ucdavis.edu/pdf/UCD-ARR-10-07-16-01.pdf>



Protection at bridge column



Caltrans Division of Research,  
Innovation and System Information

# Research Results

Transportation  
Safety and  
Mobility

**MARCH 2013**

**Project Title:**

Deliver a Set of Tools for  
Resolving Inductive Loops and  
Correcting Data

**Task Number:** 1116

**Completion Date:** September 30, 2012

This project developed tools and  
techniques to troubleshoot and  
diagnose problems with Caltrans'  
inductive loop detector stations.

**Task Manager:**

Joe Palen,  
Senior Materials and Research Engineer  
[japalen@dcn.org](mailto:japalen@dcn.org)

## Repairing Inductive Loop Problems in Roadway Traffic Detector Stations

*New detector diagnostics resolve faulty data issues*

### WHAT WAS THE NEED?

At any given time, approximately 30 percent of Caltrans' roadside traffic detection stations generate data that is questionable in accuracy and therefore unusable, according to PeMS (Performance Measurement System), the Caltrans-wide traffic database repository. Because of challenges related to determining the causes for the inaccuracies, this situation has remained mostly unchanged over the last decade, during which time considerable effort was spent with little improvement to the malfunctioning stations.

### WHAT WAS THE GOAL?

The project's goal was to develop effective tools and techniques to diagnose and troubleshoot detection station malfunctions, thus allowing Caltrans to repair as many of the unreliable units as possible.



*The algorithms and approaches  
developed in this project  
synergize with the C1 Reader,  
a tool for finding and correcting  
loop data errors.*



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and implementing solutions.

## WHAT DID WE DO?

At the project's outset, the raw data generated from the inductive loop detector cards was assessed and fed into Type 170 and 2070 signal controllers. It became clear that a sizable amount of usable information generated by detection stations was currently being bypassed or discarded. The research team learned that single loop detector stations—most commonly installed in Southern California—were generating more accurate speed and vehicle classification information than was generated elsewhere. Comparing the single loop results with those generated by dual loop installations, which are more typically installed in Northern California, validated this improved level of accuracy.

Researchers also realized that useful information could be derived from the raw loop detector card data that was not currently being used. On the micro-scale, many types of individual detector card errors can be ascertained and even fixed before they aggregate to the point where a station's entire output is reduced. On the macro-scale, it was conclusively shown that the precise time of the onset of traffic congestion can be determined more quickly and accurately by examining the relationships in the raw loop data between multiple stations along the same corridor.

## WHAT WAS THE OUTCOME?

Early in the project, Partners for Advanced Transportation Technology (PATH) researchers realized that significant amounts of data generated from the traffic detector stations' low-level raw loop detector cards were not being used. PATH researchers began developing prototype tools to capture this low-level data and assess its validity, comparing the data with video of the passing traffic. However, the project was delayed due to the cost and complexity of this hardware prototyping effort, and the team turned instead to field data collection hardware and tools already in development by Caltrans.

About the same time, the team had access to a working version of VideoSync, a software application to validate detectors, as well as prototype hardware technology, called a C1 Reader, which could capture the low level loop data without interfering with the operation of the controller. The plan was for one team to develop most of the hardware used to generate the data, while another team developed much of the supplemental software that would use that data to diagnose and troubleshoot existing problems.

The VideoSync and C1 Reader, essential for capturing the low level data, project Phase 2, is currently in progress.

PATH researchers were able to develop algorithms to generate accurate speed and classification data from single loop stations, algorithms to assess each detector's viability from statistical tests, and algorithms to determine the level of congestion across multiple detection stations. The team concluded that data communication across a cellular link is much less reliable than hardwire communication. Indeed, a significant portion of the effort expended in developing the C1 Reader was correcting communication errors induced by the cellular system.

## WHAT IS THE BENEFIT?

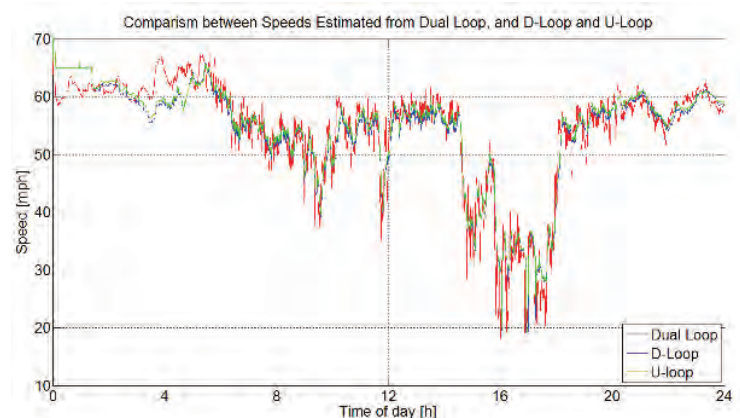
Unforeseen project delays made it difficult to efficiently coordinate with the C1 Reader Project. Once the C1 Reader hardware becomes available, which is imminent, the benefit of synergistically combining these two efforts will be realized. The researchers did achieve the following objectives during this project:

- Used VideoSync to validate detectors using methods that are in compliance with international standards.
- Developed algorithms to determine the onset of traffic congestion with high accuracy.
- Developed algorithms to determine fleet travel time between detector stations.
- Developed algorithms for generating accurate speed and vehicle classification from single loop stations.
- Resurrected detection stations currently misreporting to PeMS by using a separate communication channel, as well as a separate data processing channel, when necessary.

## LEARN MORE

See the final report:

<http://gateway.path.berkeley.edu/~xylu/files/TO6327.html>





Caltrans Division of Research,  
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# Research Results

Transportation  
Safety and  
Mobility

**JUNE 2013**

**Project Title:**

Deployment of a Tool for Measuring  
Freeway Safety Performance

**Task Number:** 1215

**Completion Date:** December 31, 2011

This project developed a software tool that superimposes freeway collision data over Transportation Management Center (TMC) maps to display the relative probability of the types of collisions that occur under different traffic conditions.

**Task Manager:**

Roya Hassas,  
Project Engineer  
[roya.hassas@dot.ca.gov](mailto:roya.hassas@dot.ca.gov)

## Enhancing a Freeway Safety Performance Measurement Tool

*Intelligent risk analysis software helps Caltrans evaluate and improve freeway safety*

### WHAT WAS THE NEED?

Freeway safety performance is measured by estimating the cumulative risk of particular collision characteristics. Collision prediction models have the potential to predict the occurrence and severity of collisions by streamlining traffic flow and reducing traffic congestion to improve safety. By incorporating collision prediction models to quantify the safety benefits accrued from smooth and efficient traffic operations, transportation management agencies can better measure urban freeway safety performance.

Still in the early stages of development, not enough research has been conducted to develop and comprehensively assess collision prediction models or to fully understand the benefits that they could bring to an agency's safety and mobility strategies. Traffic collisions have many causes, including roadway geometry, driver behavior, roadway conditions, and vehicle types. And the manner in which safety can be improved on urban freeways by using these models is not yet well understood.

### WHAT WAS THE GOAL?

The objective of this study was to develop a tool capable of predicting and assessing the risk of collisions occurring in real time. The safety analysis tool links traffic flow statistical parameters, types of collisions that can occur, varying traffic flow conditions, and the range of circumstances under which collisions occur.



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## WHAT DID WE DO?

A previous research project developed the core methodology of a tool for measuring freeway safety performance. The tool was based on transforming the raw data obtained from pavement loop detectors into 27 distinct variables that together capture the temporal and spatial dynamics of traffic flow. These variables were used to model the relative risk of various kinds of collisions on Orange County's (Caltrans District 12) urban freeways. University researchers updated the original models with more recent collisions and traffic data collected from Orange County freeways, conducted a limited deployment of a safety performance measure tool called Accident Risk Analysis (ARA) used to analyze collision risks, and validated the model predictions against actual collisions for more recent data.

## WHAT WAS THE OUTCOME?

The final product is the ARA tool, which links traffic dynamics to factors depicting a roadway's relative safety. With the ARA application, Caltrans can evaluate the safety impacts of roadway changes over time. ARA is capable of predicting even slight increases or decreases in the risk of a collision, taking freeway traffic patterns changes throughout the day into account. By summing up these probabilities over time, an overall picture of the relative safety of the roadway section emerges.

ARA is hosted by the California Traffic Management Laboratories website located at University of California, Irvine. The website provides Time Series Display plots with sufficient data, displaying the daily collision risk performance of all targeted freeway segments in Caltrans District 12.

## WHAT IS THE BENEFIT?

ARA allows Caltrans to evaluate the safety impacts of roadway changes over time, evaluating the differences in predicted collision characteristics and numbers before and after significant roadway modifications are implemented. The models indicate when the propensity for collisions inches up or down and why. The predictions are best used to evaluate the cumulative probability of collisions and collision characteristics over longer time horizons and extended stretches of roadway.

The ARA tool is well suited to examine and quantify changes in the relative safety characteristics of an urban freeway section. The methods developed should be adaptable to modeling other phenomena that are dependent on or a result of traffic flow conditions over time. While the estimated models do not perform optimally for toll roads, this is an area for future study.

## LEARN MORE

To view the report:

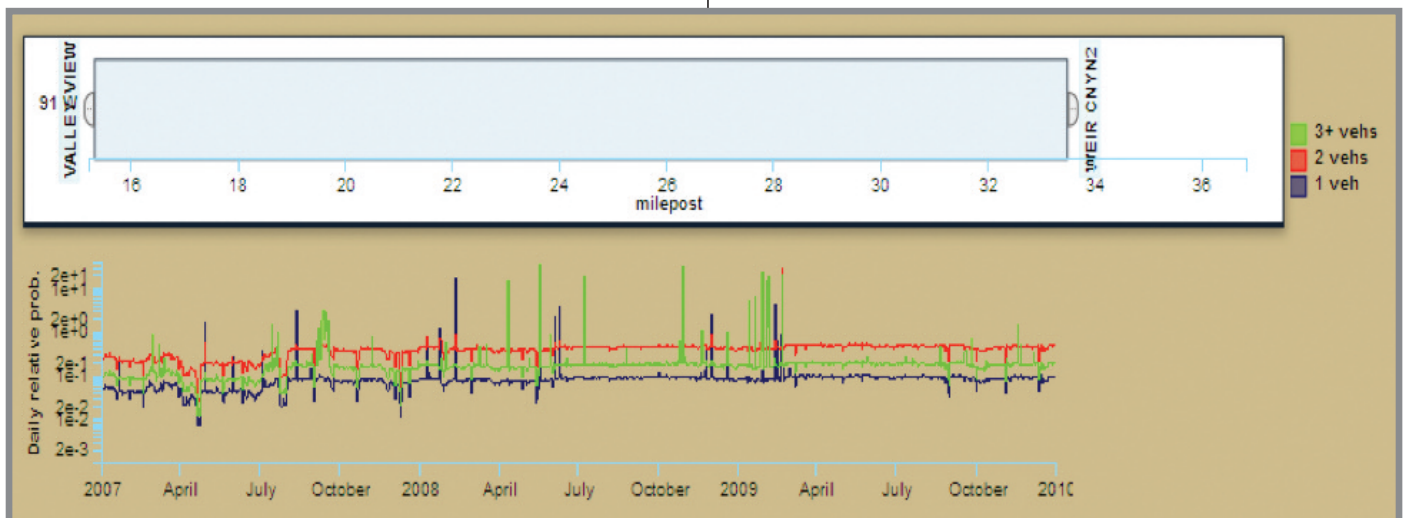
[www.dot.ca.gov/research/researchreports/reports/2011/2011-12\\_task\\_1215-tsm.pdf](http://www.dot.ca.gov/research/researchreports/reports/2011/2011-12_task_1215-tsm.pdf)

To access the ARA tool, go to:

[www.ctmlabs.net](http://www.ctmlabs.net)

Click on Projects, then Login. First time users will be required to register.

*Time Series Display plots, such as this one in Orange County (Caltrans District 12), log the daily collision risk performance of all freeway segments in that district.*







Caltrans Division of Research,  
Innovation and System Information

# Research Results

Transportation  
Safety and  
Mobility

**MARCH 2013**

## Project Title:

Intelligent Roadway Information System (IRIS) Technical Support and Testing

**Task Number:** 1777

**Completion Date:** December 31, 2011

This project tested, enhanced, and implemented a unified, open source traffic management software system tailored to meet the requirements of Caltrans rural districts.

## Task Manager:

Roya Hassas,  
Project Engineer  
[roya.hassas@dot.ca.gov](mailto:roya.hassas@dot.ca.gov)

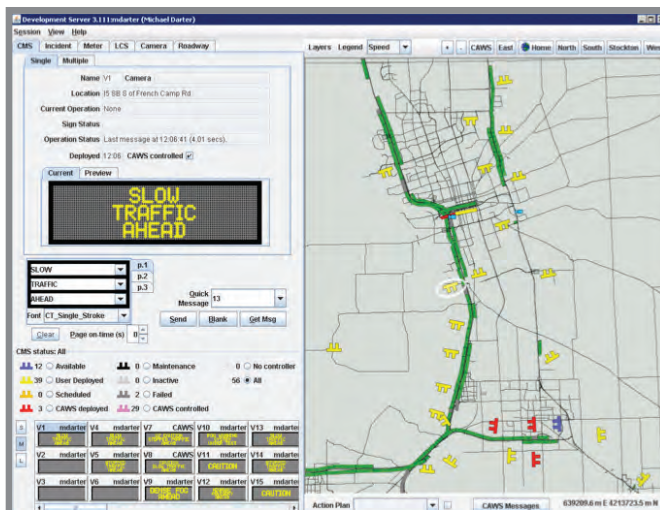
## Intelligent Roadway Information System (IRIS) Transportation Management Software

*Implementing a low-cost integrated traffic management system for rural areas to improve the mobility and safety of travelers*

### WHAT WAS THE NEED?

The Caltrans urban Transportation Management Centers (TMCs) use the Advanced Traffic Management System (ATMS) software tool, which provides real-time information on highway conditions to detect traffic incidents, manage the flow of traffic, and disseminate traveler information. ATMS helps Caltrans reduce commuting times, maximize roadway capacity, and generally provide safer traveling routes. It also provides operators with unified access and control to multiple types of roadway devices rather than having to operate disparate systems.

ATMS is composed of several proprietary software solutions that are expensive to acquire. The recurring maintenance costs have also been increasing. Caltrans rural districts often cannot afford the initial setup cost, let alone the recurring costs associated with development and operation. In addition, rural districts do not have the same mobility needs as large metropolitan regions and therefore do not require many of the advanced features and capabilities that ATMS provides. As a result, Caltrans rural districts have addressed traffic management by developing disparate solutions with non-uniform management, administration, and operating protocols.



IRIS user interface



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## WHAT WAS OUR GOAL?

The goal was to enhance, test, and evaluate the Intelligent Roadway Information System (IRIS) software, a low-cost open-source alternative for rural districts that provides functionalities comparable to the ATMS software.

## WHAT DID WE DO?

The Minnesota Department of Transportation (DOT) developed the open-source IRIS software tool and made it freely available in 2007. IRIS offers a collaborative and shared-development environment. Caltrans is the first transportation agency to adopt IRIS and explore its capabilities. The demonstration location chosen was Stockton in Caltrans District 10. A pilot test with limited features was also performed in Districts 1, 2, and 5.

The UC Davis Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center, in partnership with Caltrans and the Minnesota DOT, did the following:

- Collaboratively developed enhancements and extended IRIS to be compatible with the Caltrans District 10 infrastructure and field devices.
- Adapted IRIS to match the district's specific nuances and operational needs.
- Integrated IRIS with existing District 10 hardware and software systems. Enhancements were contributed back to the Minnesota DOT for use by other public and private agencies.
- Modified IRIS to assume the functions of a legacy middleware system that was responsible for acquiring all vehicle detection and weather information from field devices as well as the Automated Warning System for District 10.
- Performed extensive user acceptance and operational testing prior to deployment.

## WHAT WAS THE OUTCOME?

IRIS is fully deployed in District 10. The number of software applications and servers in District 10 has been reduced, with IRIS assuming more roles. The system is reliable and flexible and provides a unified tool and interface for controlling and monitoring field devices. IRIS addresses some of the same features that Caltrans has come to rely on with ATMS installations in urban areas, such as increased public safety, transportation efficiency, sustainability, and the fostering of transportation management innovation. Study results showed that IRIS can dramatically lower costs compared with proprietary systems. It is estimated that the initial and ongoing system costs would be 72% lower than a proprietary system. IRIS capabilities improve safety and lower personnel maintenance needs.

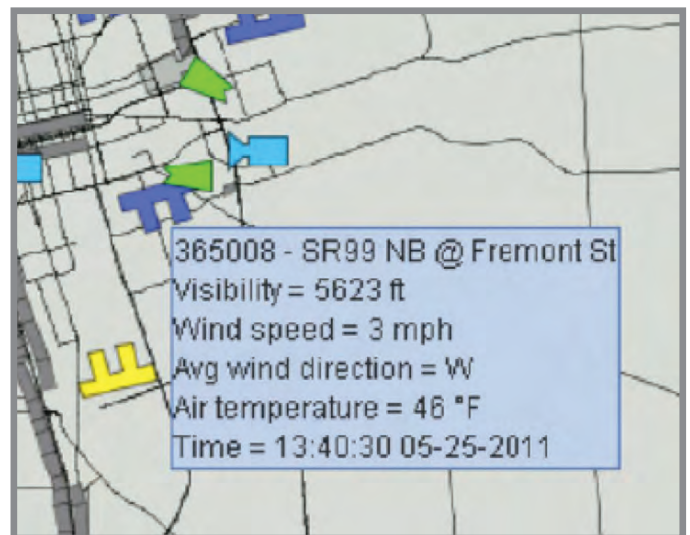
## WHAT IS THE BENEFIT?

IRIS has shown to be an effective and affordable transportation management system for rural TMCs. The collaborative, open-source IRIS system has the potential of increasing the rate of transportation technology innovation for Caltrans. Access to the IRIS source code is not restricted by legal agreements, allowing other public and private transportation agencies to use and modify it. IRIS's accessibility and lower cost will increase the rate of innovation and use by Caltrans staff, researchers, students, and innovators.

## LEARN MORE

To view the full report:

[www.dot.ca.gov/research/researchreports/reports/2011/2011-12\\_task\\_1777-tsm.pdf](http://www.dot.ca.gov/research/researchreports/reports/2011/2011-12_task_1777-tsm.pdf)



Road Weather Information System



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Notes

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**California Department of  
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**Division of Research, Innovation,  
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